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MANNED ENVIRONMENTAL  
SYSTEM ASSESSMENT

Prepared under Contract No. NASw-658 by  
THE BOEING COMPANY  
Seattle, Washington  
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## MANNED ENVIRONMENTAL SYSTEM ASSESSMENT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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INTRODUCTION

The Boeing Company has successfully conducted a manned environmental system assessment (MESA) program for the National Aeronautics and Space Administration (NASA) under the reference contract. The test has demonstrated experimentally that 5 men can survive for 30 days in a closed self-sustained integrated system environment. The regenerative system included chemical, physio-chemical and biological subsystems.

A July, 1963 test attempt was aborted after 4 1/2 days due to nausea of the crew and subsystem equipment malfunctions. Thereafter, an intensive program was undertaken to insure success of the next 30 day attempt.

An integrated system 17-day test was conducted in February, 1964, with the last 4 days manned. The 30-day manned test was begun on March 2, and successfully completed on April 1, 1964.

Included herein are the subsystem development and tests, integrated system test results and recommendations and conclusions. This data should be useful to engineers and scientists of future life support systems.

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SUMMARY

The intent of this program was to investigate the many aspects of a closed operating life support system including man. Data was to be derived from a 30-day test which would include 5 men and the required life support systems such as; chemical atmospheric control, trace contaminant control, biological waste treatment, water recovery, personal hygiene and freeze-dried food. Test bed was the Boeing high altitude chamber with minimum leakage capability.

Systems selected for this test were not optimum for a 30-day mission, zero gravity or weight. Selection was based on obtaining a mixture of chemical, physio-chemical, and biological systems which would provide broad data when tested as an integrated system.

This program had two distinct phases:

- A. MESA I . From program start to end of July 1963, 30-day attempt which aborted after 4 1/2 days.
- B. MESA II. From July 1963 abort, through redevelopment and subsystem testing, ending with the successful completion of the March 1964, 30 day test.

MESA I

The program started in March 1963. All systems were designed, limited subsystem tests conducted and the 30-day manned attempt started in July 1963. It was aborted after 4 1/2 days due to extreme nausea, loss of appetite and systems' malfunctions. All systems presented major operating problems requiring continued maintenance and repair. The final failure was the rupture of the waste reactor which caused immediate abort. Efforts to medically pinpoint the cause of the sickness were unsuccessful. It has been reasoned, therefore, that the abort was caused by many items and when coupled together presented an insurmountable hurdle to the crew. Some of these could be:

- A. The undesirable sweet pungent odor in the chamber.
- B. Possible small quantities of gases which by themselves would not be toxic; such as NO<sub>2</sub>.
- C. Yellow condensate which indicated an atmospheric contaminant (or combinations) of long chain compounds.
- D. Requirement to repair the waste reactor centrifuge and the resulting psychological effect.

- E. Continual system repairs.
- F. Lack of the ability to maintain a uniform schedule and the resultant confusion and loss of sleep.

It should be noted that for the first time all systems including man were sealed in a chamber with minimum leakage. Apparently toxicological problems were much greater than anticipated and the necessary trace management was not exercised. Therefore, MESA I showed the extreme importance of trace contaminant control in an integrated system with its many unknown interactions.

## 5.2

### MESA II

As a result of the MESA I abort a detailed program was conducted to ensure success in the next 30-day, 5-man attempt. This program had as its objectives:

- A. A revision in the toxicology philosophy using a conservative engineering approach; complete material re-evaluation, using only known compounds, laboratory accepted and the installation of additional contaminant removal equipment.
- B. Further chamber testing of the MESA I configuration in an attempt to pinpoint a toxic element.
- C. A systems engineering approach to all subsystem designs to ensure meeting all old and new requirements and to ensure reliability and/or ready maintenance.
- D. Laboratory component and subsystem testing to ensure meeting the requirements; define new requirements; to provide system operating limits; and to provide subsystem reliability.
- E. Preparation of the necessary documentation to conduct a test of such a large magnitude.
- F. A 17-day integrated chamber test was conducted to provide the necessary confidence in the system to conduct the 30-day manned test. The first 13 days were unmanned. This allowed for exploration of gas generations and removals, such as  $\text{NO}_2$ , operating procedures for the sodium superoxide waste and water systems, as well as system replacement rates of actual elements such as filters. The last four days of this test were conducted with 5 men inside the chamber. All subjects came through with no recurrence of the symptoms of the July, 1963 abort. Information gained from this test provided the necessary confidence and data to conduct the 30-day, 5-man test.

The 30-day, 5-man test started at 1355 on March 2 and was successfully concluded at 1355 on April 1, 1964. Section 6 includes results and conclusions of this test. Reviewed below is the pertinent information obtained.

A. Crew

1. Physiological

Pre-test, test and post-test medical monitoring showed the crew suffered no ill effects from the test. At one point in the test 4 of 5 crewmen showed a definite increase in Met. HBG. Further readings were normal and no explanations for increase in oxides of nitrogen except possible preservatives in the Gemini diet.

Bacteria sampling was conducted on all subjects including nose, throat, mouth and fecal. During the confinement all subjects showed a decline of normal nose and throat flora and coinciding, an increase in a potentially pathogenic organism. Possible cause may have been the conditions of temperature, humidity, the bacteriological clean chamber atmosphere or trace quantities of an unknown chemical agent.

Urinary metabolites were conducted before, during and after the confinement. These included 17 Hydroxycorticosteroids, Catecholamines and calcium.

2. Behavioral

Various psychological tests were used to evaluate the behavior of a five man crew. Tests were included to assess visual and auditory functioning, perceptual and motor skills, group dynamics and individual attitudes and experiences.

No control groups were available for behavioral comparisons. The generally negative attitudes of the subjects towards the behavioral assessment program necessitated a considerable reduction in its scope before the end of the first week of confinement. This poor motivation made much of the psychological data highly questionable.

It was concluded that the MESA thirty day confinement was not particularly difficult or stressful for the crew. Those behavioral problems which did exist appeared to stem mostly from poor motivation and centered primarily around the area of interpersonal friction. It is clear that human factors considerations (difficulty of use and maintenance of equipment, crowding of the chamber, and the like) led to irritations and that these often led to covert interpersonal friction as well.



### 3. Nutrition

Thirty days of food was contained within the chamber and consisted of freeze-dried and dried diets. Ten days utilized the Gemini diet with 90°F water and the last twenty a space station diet with 45° and 165°F water. A detailed analysis of the diets is to be made by Houston Manned Space Center. In general the food was one of the major annoyances to the crew. In general, the crew stated that "crew morale could be increased by providing, in addition to nutritional value, food which was presentable and palatable". All stated that meals were one of the enjoyments of life and should be so treated in space flights.

In summary all crewmen functioned with the systems fairly well. The length of training was marginal and a more exact method of crew selection could have resulted in a more motivated crew. However, it should be noted that crew did provide the required function; that is to complete the integration of man and machines and provided considerable information for future system designers.

#### B. Systems

One major accomplishment during this test was the attainment of a closed atmosphere. In the 2400 F<sup>3</sup> chamber only 200 F<sup>3</sup> of nitrogen was added to maintain a positive, 2" H<sub>2</sub>O pressure above outside ambient. This resulted in utilizing approximately one atmospheric volume during the entire 30-day test and retaining and treating all of the contaminants generated by systems and man.

No appreciable trace contaminants were measured which could be toxic to man. It is considered that the Hopcalite burner, Chemical/Bacteria/Radiation (CBR) filter and the humidity condensate effectively removed and controlled the chamber atmosphere to an acceptable level.

The performance of the sodium superoxide (NaO<sub>2</sub>) beds in controlling O<sub>2</sub> was very successful. This system provided to be a very simple and easy to operate in controlling the O<sub>2</sub> between 19% and 21.5%. Control of CO<sub>2</sub> to below .75% was not always available from the NaO<sub>2</sub> beds. Lithium hydroxide was used as a backup and its performance was very good. Certain improvements in the NaO<sub>2</sub> system should result in better CO<sub>2</sub> control.

The humidity underflow system was separated from the water system in order to determine if it would be a ready source of potable water. The system included a bacteria filter, ion exchange and charcoal filter. Test results indicate the underflow was a very effective remover of atmospheric contamination. However, in doing so the condensate COD's increased rapidly and required excessive changes in charcoal filters to maintain the water standard COD.

The waste system provided was a biologically-activated sludge system using an aerobic culture. Realizing this type of system is probably a closed ecological system, it did provide cabin contaminants which had to be controlled, both chemical and biological. Development showed that with this particular system there is a narrow band within which it must operate. Proper aeration must be controlled with feed amount and rate to keep it between the anaerobic state and a condition of high  $\text{NO}_2$  generation. By continual monitoring of dissolved oxygen and exhaust gas nitrites the system performed very well.

In keeping with the waste system concept effluent from this system was utilized by the water system to provide potable water. Although the filtration, catalytic oxidization and UV sterilization performed as expected, considerable maintenance was required with the evaporator. Since the effluent from the waste system contained suspended solids, the evaporator and tubing required constant attention to ensure operation.

Water usage during the test leveled out at approximately 26 liters/day/5 men. This included all but the shower water, and indications were that the crew could have comfortably managed on less. Total water produced was 507 liters from the water system and 237 liters from the humidity underflow. Approximately 43% of this water was rejected due to exceeding the bacteria limits of 25,000 total count/ml, and 2.2 coliform/100 ml. It was found that contamination could and did occur after the bacteria treatment in the potable water tanks. Of the total water produced, approximately 45% was recycled for crew drinking and personal hygiene.

A specially designed shower system was provided which used its own regenerated water. Soap and dirt were to be removed by floc, charcoal filter and ion exchange. Through the entire run there was always a problem of ensuring complete removal of the soap. The proper balance of lime to soap was never obtained and the system never performed up to expectations.

### 5.3 INFORMATION GAINED AND RECOMMENDATIONS

The successes and failures of this program have provided information and resulting recommendations for the future. A summary of the major areas follows:

- A. Proved the concept of life support in a sealed atmosphere.
- B. Toxicological problems in a sealed atmosphere are greater than expected and integration testing is the only way to make final judgment.

- C. Bacterial contamination in space can occur and system re-sterilization must be available.
- D. Humidity underflow effective contaminant remover, but questionable ready source of potable water.
- E. Need standards of toxicological limits and efficient quick methods for measuring.
- F. Personal hygiene equipment can be source of contaminants both toxic and bacteria. Must maintain strict control on all designs.
- G. Need standards for water acceptability and the necessary monitoring equipment.
- H. Need standards for bacteria limits and the necessary monitoring equipment.
- I. Hopcalite burner and full system filtration (similar to CBR) is very effective in controlling trace gases and bacteria.
- J. Proved that chemical ( $\text{NaO}_2$ ) is a very effective and mechanically simple system for atmospheric control. The simplicity of this concept should be weighed versus reliability of other concepts during trade studies. Further trades should be made and at a minimum consideration given to use of this system for emergency back-up, personnel short term systems and the like.
- K. Established the control variables for a biological aerobic waste system. Consideration of this concept must be coupled with water system. To ensure an efficient waste-water recovery system additional development is required in the separation of solids prior to water treatment.
- L. These tests have resulted in considerable acquired knowledge in the conduct of continual, long term manned tests.
- M. Future planners of long term tests should seriously consider the time and procedures for crew selection and training.

6.0

## DISCUSSION

6.1

### INTEGRATED SYSTEM

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A complete integrated life support system capable of providing life support for 5 men for 30 days was developed, designed, fabricated, and installed inside the Boeing variable altitude chamber for test. The first test attempt in July 1963 ended after  $4\frac{1}{2}$  days because of crew illness and a catastrophic equipment failure. Prior to resumption of the second attempt all subsystems were reviewed for performance and modified as required to insure reliable mechanical operation. Trace contaminant studies were made resulting in the substitution of many equipment fabrication materials, additional filtration, and increased capacity air catalytic oxidization. The second attempt was started in March 1964 and was successful.

Discussed herein are all aspects of the program including systems, technology, behavioral and medical and clinical. Individual development, subsystem and system tests, results, analysis, conclusions, and recommendations are included. To assist the reader, discussions are chronological in order covering the two basic periods:

Author

#### MESA I

Chronological from program start March 1963 up to and including the July 1963 attempted 30 day manned test which ended after  $4\frac{1}{2}$  days. Included are two system tests, a 2-day 5-man checkout followed by the 30 day attempt.

#### MESA II

Chronological from the end of the July attempt to the completion of the March 1964, 30-day manned test. Included are two system tests - a 17-day integration (13 day unmanned, 4 day manned) and the 30 day, 5 man test.

6.1

### SYSTEMS

The integrated system selected for evaluation during this program consisted of the following subsystems:

- A. Chemical atmospheric regeneration using sodium superoxide and lithium hydroxide to maintain a 21/79 atmospheric composition.
- B. Filtration and high temperature oxidization for trace contaminant control.

- C. Outside cooled circulation glycol heat exchanger for temperature and humidity control.
- D. Biological activated sludge system for treating the crew waste and supplying effluent for water processing.
- E. Water treatment system using high temperature catalytic oxidation and multi-filtration.
- F. Regenerative multi-filtration shower system and wash basin for personal hygiene.
- G. Hot and cold water and storage boxes for food preparation.
- H. Sleeping, eating and storage facilities.

Block diagrams of the Integrated Systems used on MESA I and MESA II Programs are shown in Figure 1 and Figure 2 .

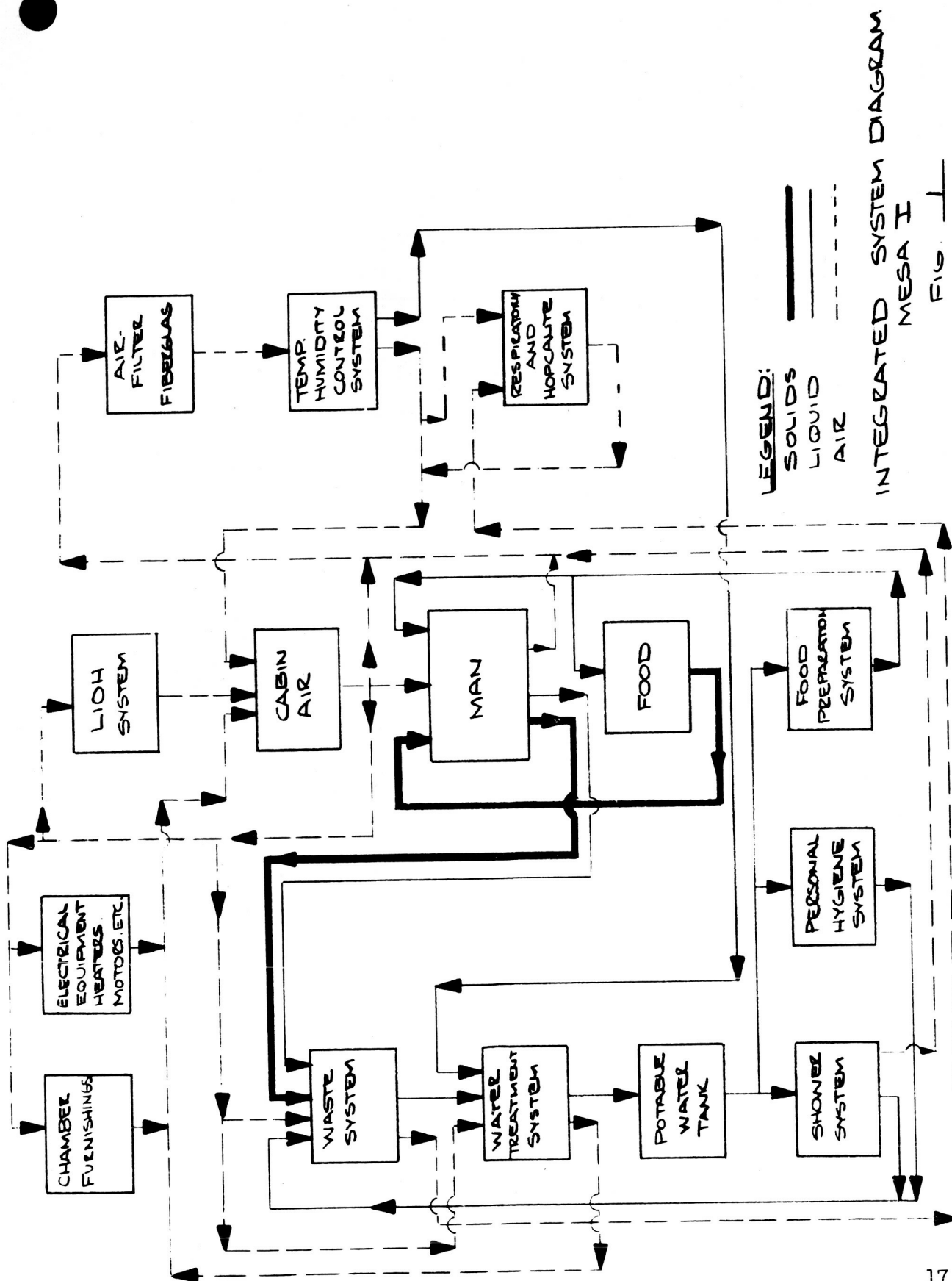
Detail system schematics can be found in Boeing Document D2-90487-1 System Manual.

All equipment was installed within a sealed chamber capable of minimum leakage. The atmosphere was held at a minimum of 2" H<sub>2</sub>O above the outside ambient pressure. Leakage was made up by nitrogen.

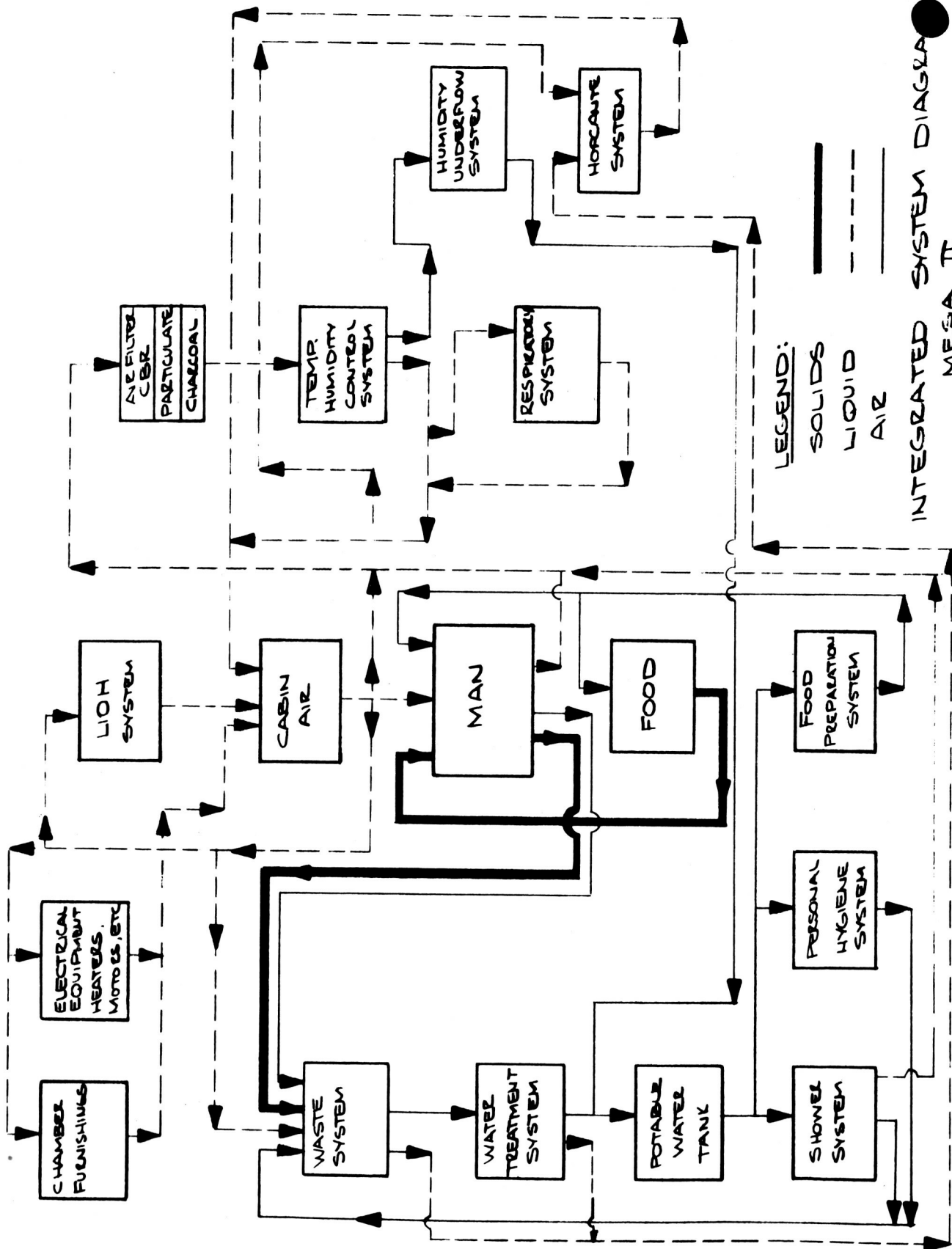
It should be noted that systems are not optimized for mission or space. The intent of the program was to investigate the interactions of man and systems. As an example the biological waste system would be considered for very long missions with a completely closed system and the superoxide for O<sub>2</sub> and CO<sub>2</sub> is considered for short mission durations. Systems were not optimized for weight, zero gravity and in the most part fabricated from commercial components.

The MESA Program has demonstrated the Integration of Man with a Biological System and other complex Chemical, Mechanical, and Electrical Systems in a closed environment.

When combining systems of various concepts certain interactions between subsystems are experienced. To portray the effects of one subsystem on another block diagram are presented in Figure 3 through 8 .

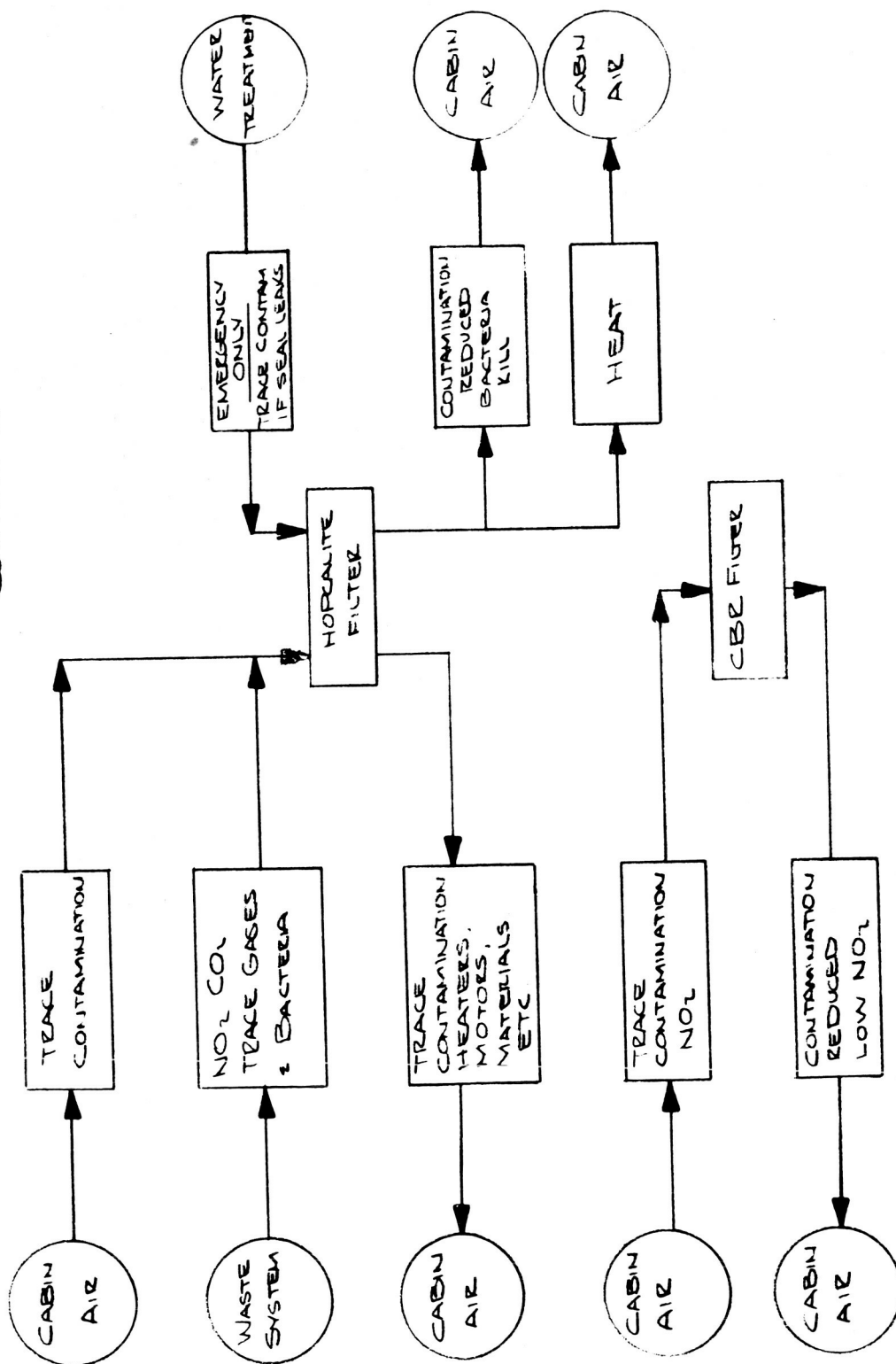


INTEGRATED SYSTEM DIAGRAM  
MESA I  
FIG 1



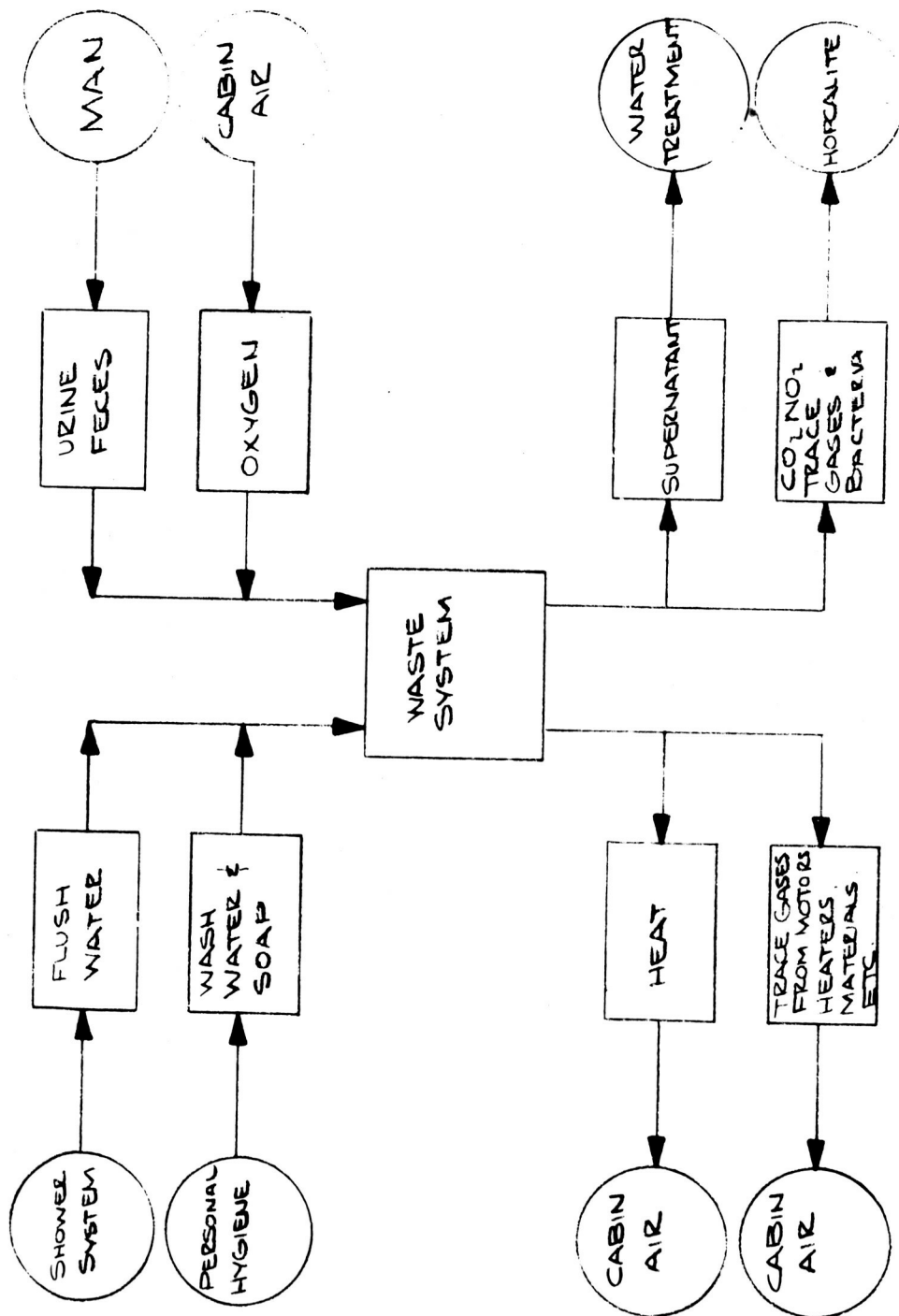
INTEGRATED SYSTEM DIAGRAM  
MESA II  
FIG. 2

NOTE: RESPIRATORY AND TEMPERATURE AND HUMIDITY CONTROL SYSTEMS ALSO CONTRIBUTE TO TRACE CONTAMINATION CONTROL OF CABIN AIR

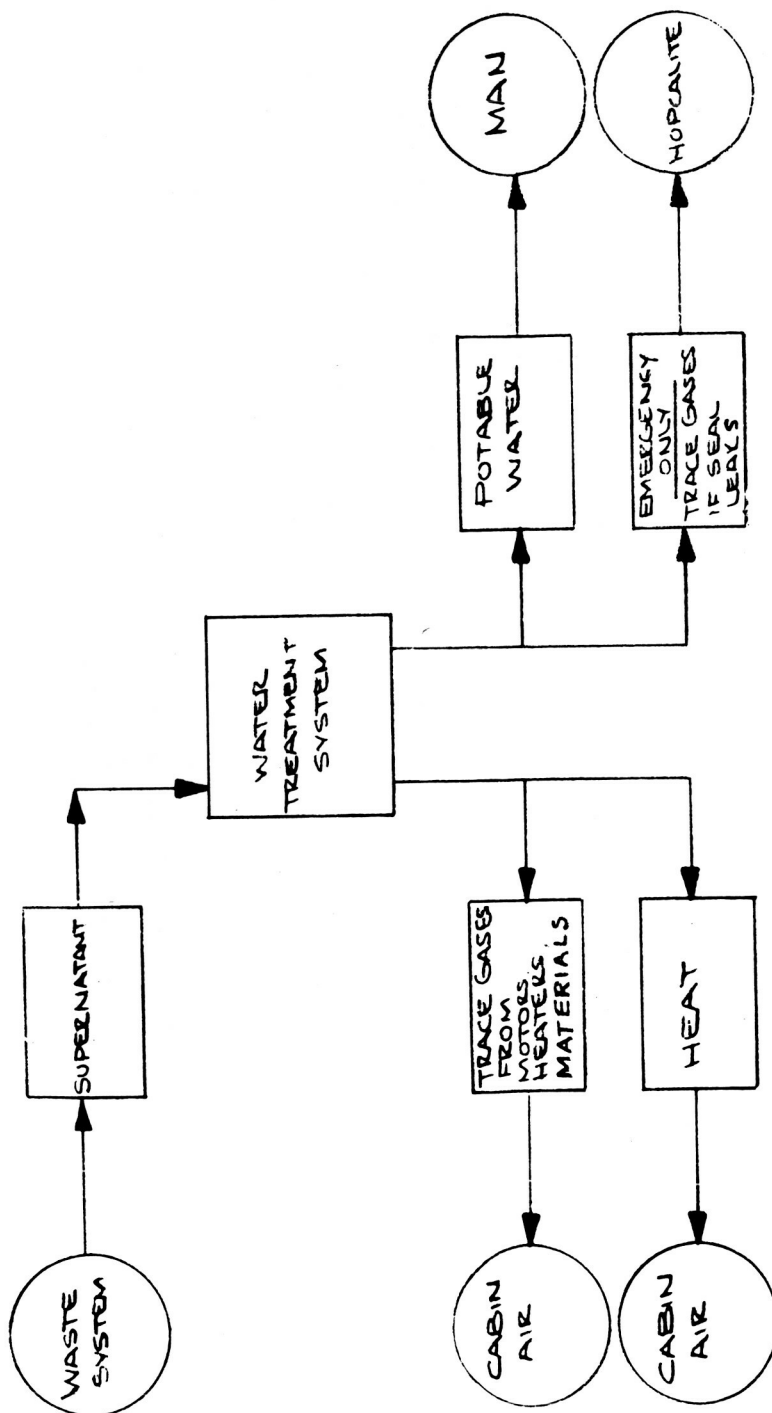


TRACE CONTAMINANT REMOVAL SYSTEM  
MESA II  
FIG. 3



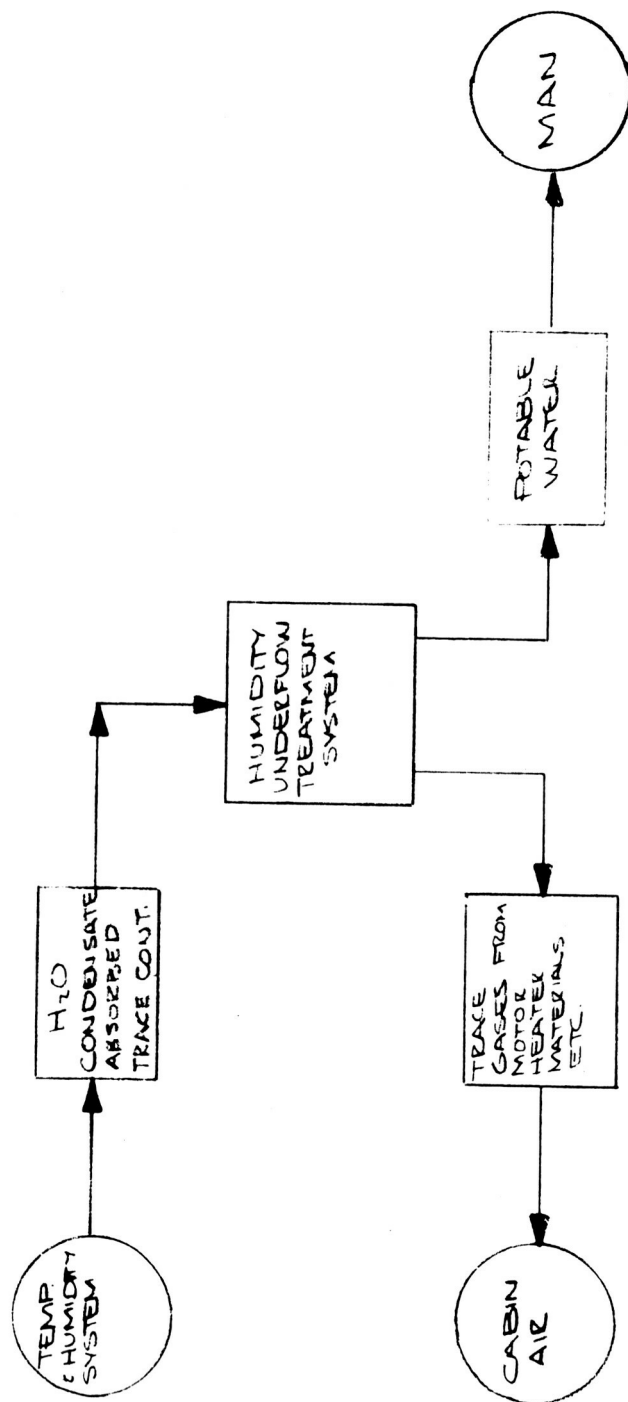


WASTE SYSTEM  
MESA II  
FIG. 4



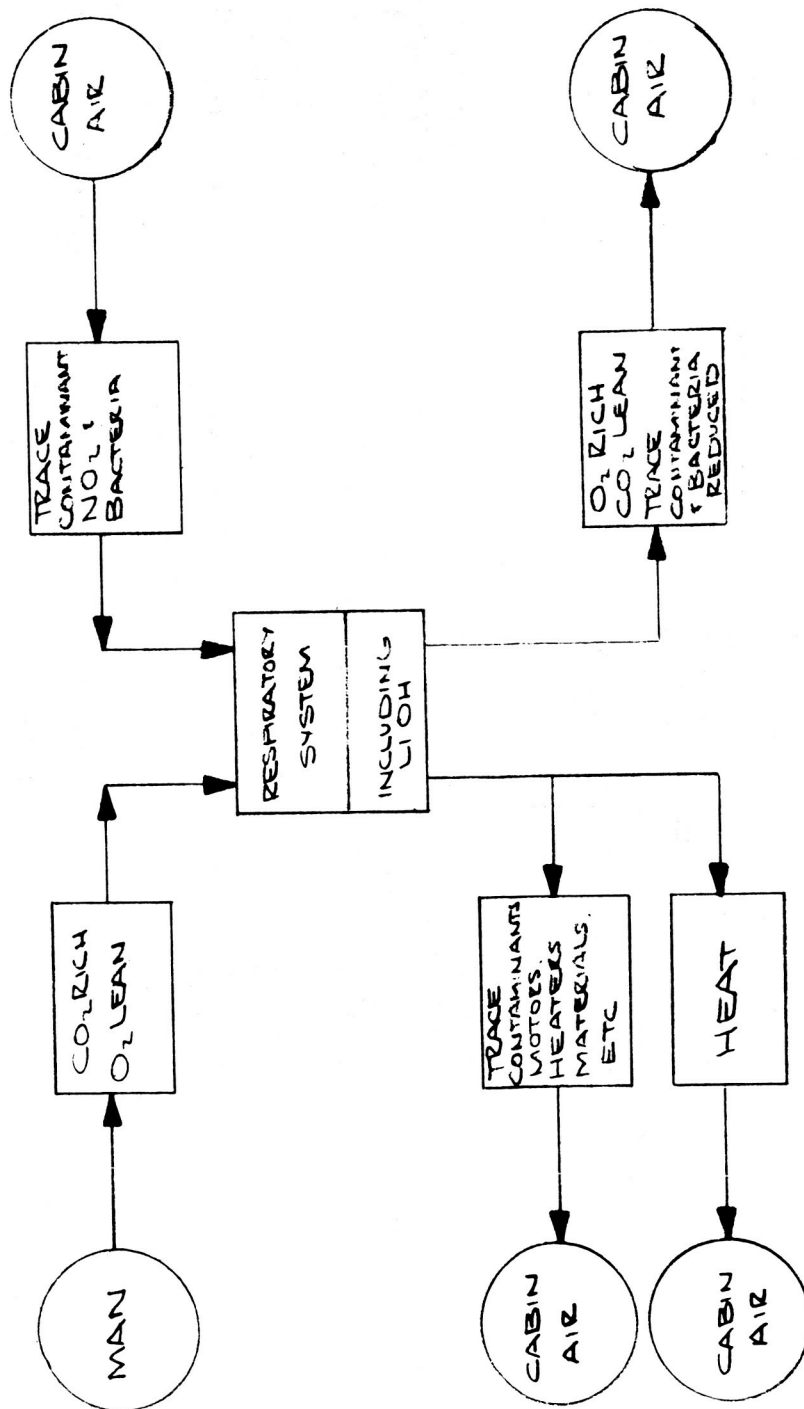
WATER TREATMENT SYSTEM

MESA II  
FIG. 5

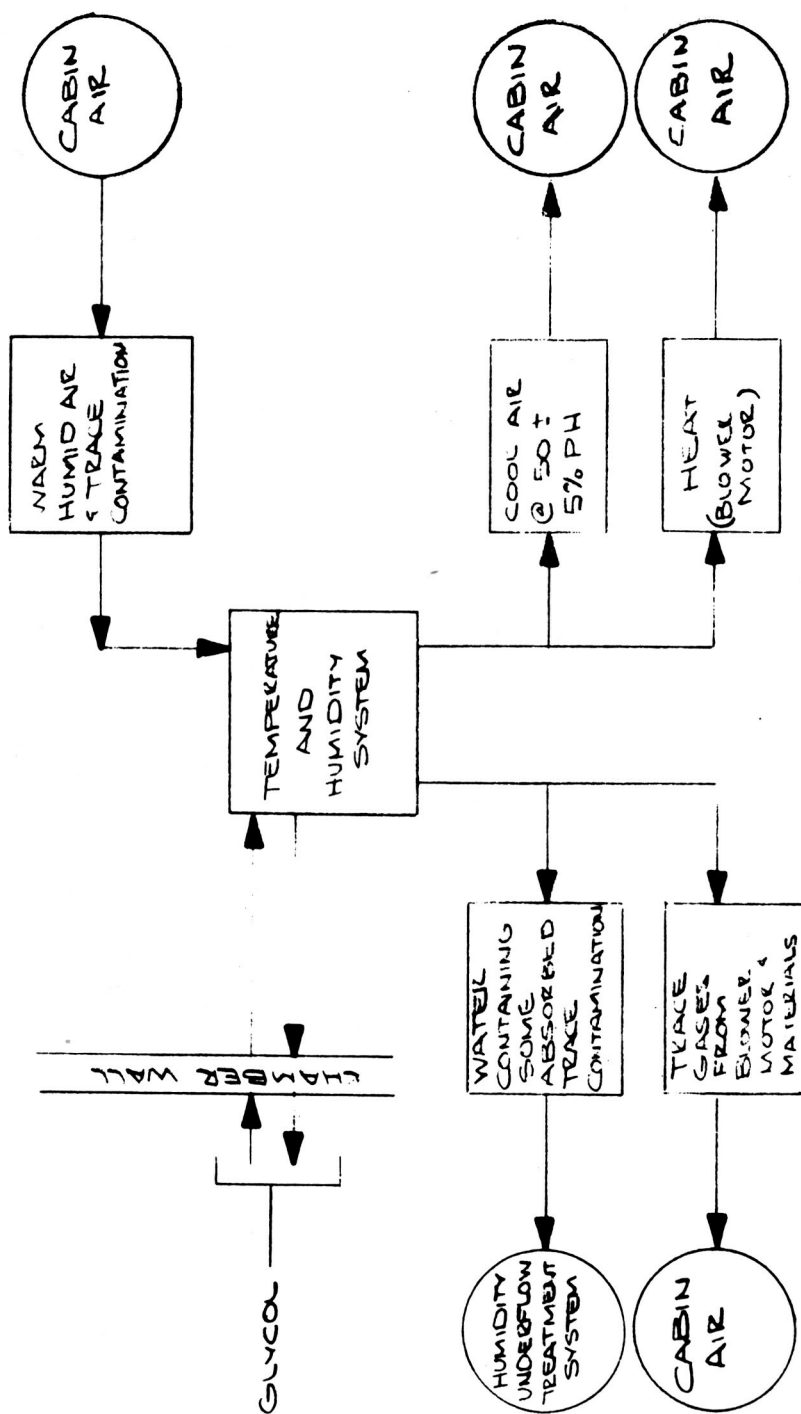


# HUMIDITY UNDERFLOW SYSTEM

MESA II  
FIG. 6



RESPIRATORY SYSTEM  
MESA II  
FIG. 7



TEMPERATURE AND HUMIDITY CONTROL SYSTEM  
MESA II  
FIG. 8

6.1.2

## TRACE CONTAMINANT CONTROL

6.1.2.1

### MESA I

#### DEVELOPMENT

The approach to trace contaminant control for MESA I was tempered by three factors; 1) the apparent freedom from contamination problems in previous chamber tests, 2) the reported wide variety and high concentration of contaminants in submarine atmospheres with no adverse effects, and 3) the lack of experience in the closed system testing of totally integrated life support systems.

In a previous 7 day chamber test the respiratory system (sodium superoxide and lithium hydroxide) was essentially the only self-contained system. The processing of waste and water recovery was accomplished externally. The air change experienced in this test was very rapid compared with MESA I. A buildup of carbon monoxide which could have resulted from smoking, arcing of carbon brushes on motors, etc., necessitated one complete purge and air change.

It was recognized that materials containing volatile solvents and materials exposed to elevated temperatures could contribute contaminants to the MESA I atmosphere. For this reason it was decided that none of the plywood furnishings should have protective or decorative finishes applied. The evaluation of materials exposed to high temperature environments was based, to a large extent, on supplier's maximum operating temperature limits. Most of these limits are established on a functional basis rather than on the temperatures at which contaminants are evolved. In certain cases laboratory testing revealed that the materials selected were unsatisfactory for the usage intended. A typical case being the resin bonded glass fiber thermal insulation material for the Hopcalite heater unit and the high temperature adhesive with which it was attached. This material was removed and replaced with a woven asbestos tape.

Five elements in the system were expected to provide the required air purification. Sodium superoxide beds were expected to provide primary service in air purification in addition to oxygen production and CO<sub>2</sub> removal. As the waste disposal unit was considered the most significant source of contaminants, the effluent gas stream from it was directed through a charcoal filter and then directly into the sodium superoxide beds. The charcoal filter was installed to remove the essentially non-reactive organic contaminants and leaving the superoxide the job of oxidizing and/or absorbing the acid gases and the more reactive organic species. The filter was a MSA No. CR-46727 cartridge for a one man gas fume respirator. It is approved by the Bureau of Mine for this application. The carbon bed was 3 1/4 inches in diameter, 1 inch deep and weighed 93 gms. The flow through the unit was 1 CFM.

A flow of 5 CFM from the gas stream emerging from the sodium superoxide beds was heated to 600°F and passed through a Hopcalite burner. This unit was included to remove CO, H<sub>2</sub>, and oxidizable organics. Previous Boeing experience in the development and utilization of Hopcalite burners on B-52 aircraft indicated that even very refractory synthetic lubricating oils could be removed from the atmosphere by such a unit at 600°. The unit consisted of a stainless steel case, one Hopcalite filter assembly MSA #SM CV8644, four 950 watt Calrod electrical heating elements, and a temperature indicating controller. The Hopcalite filter assembly consisted of stainless steel frames and hardware cloth, glass scrim cloth, felted AA glass fibers and approximately 6 pounds of catalyst. The assembly was 11 1/2 inches square and 1 1/2 inches deep.

A platenized alumina catalytic oxidizer bed operated at 1100° was incorporated into the water system to convert contaminants from the evaporator into harmless products. It was anticipated that acid gases which might result from this treatment would be collected in the condensed water and removed in the ion exchange system.

Two UV lights were placed in the respiratory system air stream for purposes of control of airborne microorganisms.

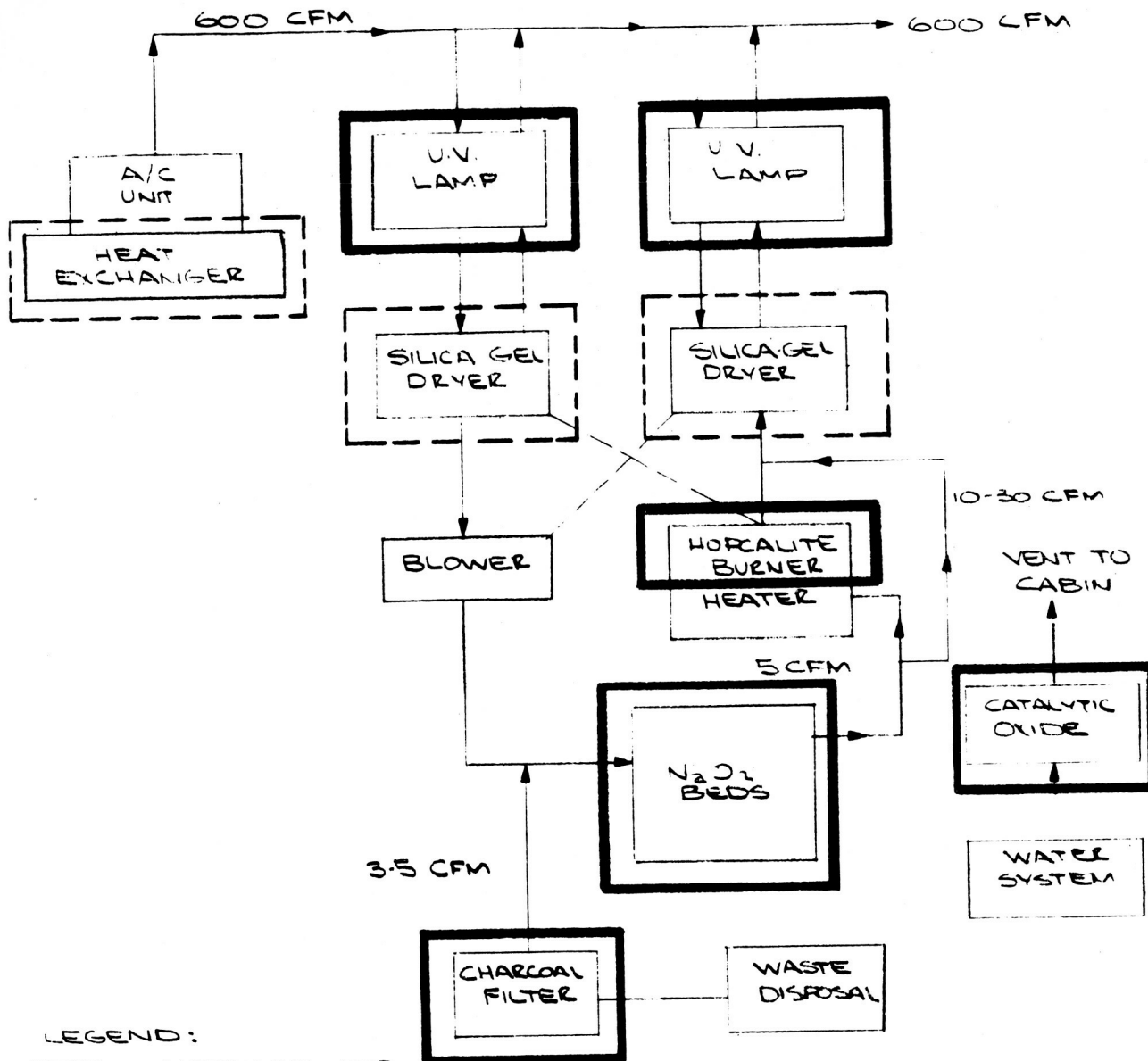
Two portions of the air conditioning respiratory systems provide assistance in the control of contaminants as a secondary function. The condensate formed in the air conditioning heat exchanger collected water soluble gases from the air conditioning stream; the silica gel beds in the respiratory system processed all of the air passing through this system both at ingress and egress.

The arrangement of the air purification system is shown in Figure 9.

#### SYSTEM TESTS

During the two day manned run, overheating occurred in the Hopcalite unit; the temperature rising to above 850°F. During this period the insulation scorched and, undoubtedly, the gasket materials decomposed. The result was a very irritating odor with accompanying irritation of the eyes, nose and throat. Ammonia-like odors were observed in the toilet area. None of the crew members reported nausea or other symptoms which might be related to contaminants.

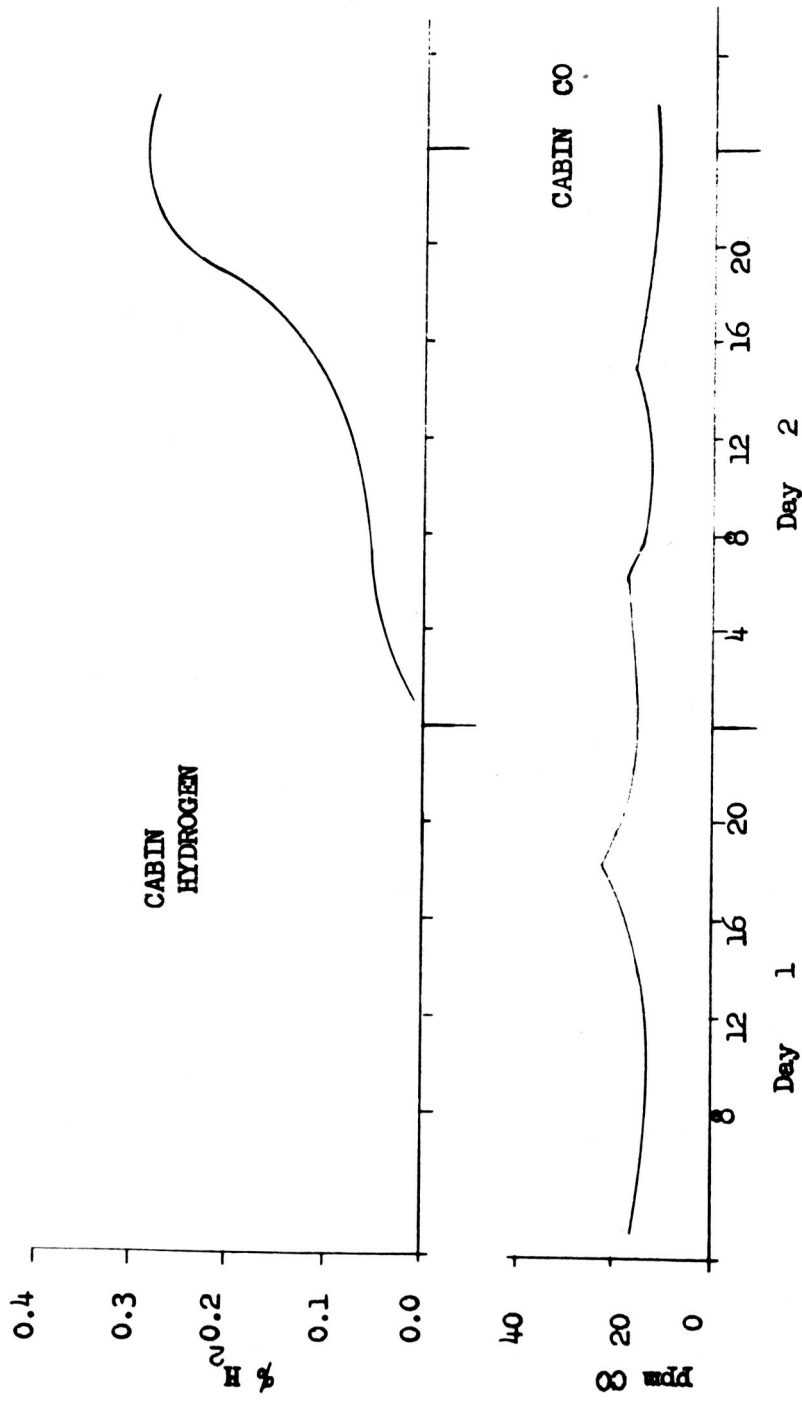
Hydrogen developed in the sodium superoxide beds increased in concentration in the cabin to a maximum of 0.3 % as shown in Figure 10. The data indicated significant reduction across the Hopcalite unit at times. The large by-pass ratio (from 2-6 to 1) and the wide temperature variation in the Hopcalite unit (from 129°F to approximately 600°F) kept this unit from controlling the hydrogen.



AIR PURIFICATION SYSTEM  
MESA I

FIG. 2





HYDROGEN - CARBON MONOXIDE  
 MESA I-2 DAY MANNED TEST

FIG. 10

The rather constant CO concentration in the cabin, (about 13 ppm), Figure 10 presents a problem. The source could readily have been the partial oxidation of organics in high temperature environments. However the data did not show a reduction to zero across the Hopcalite. One possible explanation of this could be the partial oxidation of gasket materials located between the Hopcalite bed and the sampling port or a similar fate to the Neoprene sampling tube.

In the intended 30-day run, the buildup of contaminants as evidenced by both analyses and subjective observations of odor proceeded quite rapidly. By the end of the second day disagreeable, sickening odors were reported by several members of the crew.

The inability to control the temperature to the silica gel driers with the configuration originally installed for the 2-day test required that the Hopcalite temperature be held to a maximum of 350°F. This temperature is not high enough to effectively control hydrogen which was again being introduced from the reaction of aluminum and the superoxide chemicals. Figure 11 provides a history of hydrogen concentration.

When it became apparent that the build-up of odors was increasing and causing distress to the crew the waste reactor was a strong suspect. The configuration was changed to allow the waste reactor effluent gas stream to pass directly from the charcoal filter thru the Hopcalite unit. This action eliminated any potential removal of contaminants from the waste system by the superoxide but also eliminated the by pass around the Hopcalite burner. This did not appear to offer improvement.

There was no appreciable build-up of CO during the test. Traces were found in the cabin and up to 2 ppm in some of the systems. The air processed by the Hopcalite unit read zero with respect to this gas at all times.

Although it was not sampled for during the test, 0.2 ppm of NO<sub>2</sub> were detected in the cabin shortly after the abort. Later tests showed that the air stream from the air-water separator in the water system contained up to several hundred parts/million of NO<sub>2</sub>. Thus the catalytic oxidizer in this system was oxidizing NH<sub>3</sub> to NO<sub>2</sub> at rate higher than the condensed water would remove it. It was also found that the level control arrangement in this system did not perform properly. Effluent from the evaporator was transferred to the catalyst where it charred with the evolution of unpleasant odors.

The humidity underflow condensate system scrubbed gases and/or particulate matter from the atmosphere. This was readily indicated by the yellow color of the condensate. Unfortunately no chemical analysis of the unprocessed water was made during the test. Therefore the effectiveness in air purification could not be evaluated.

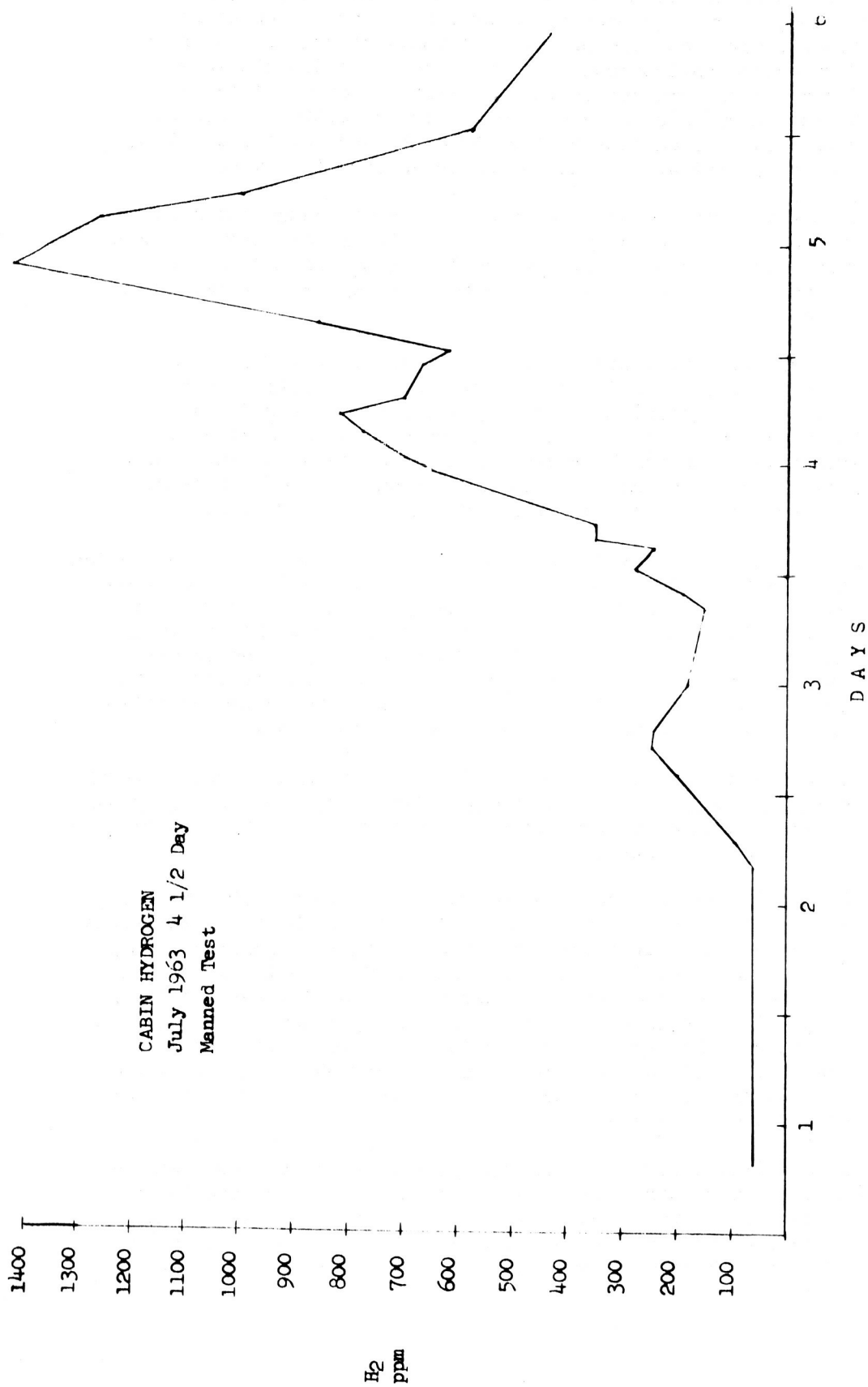


FIG. 11

The silica gel driers in the respiratory system also acquired a very yellow color indicating that they could absorb and retain contaminants.

It was concluded that trace contaminants played a significant role in the discomfort of the crew and the early termination of the test. Although the causative species were not identified it was apparent that there were material sources and the air purification concept was inadequate.

#### 6.1.2.2

#### MESA II

#### DEVELOPMENT

The presence of obnoxious odors in MESA I, the ill-health of the subjects and the data developed in the toxicological post tests indicated that the control of trace contaminants was a very significant problem area. Therefore, a comprehensive trace contaminant management program was implemented. This program had four key features:

- A. The development of criteria for classifying materials as useable or unuseable.
- B. A critical review of the materials and environments in all systems to eliminate contaminant sources.
- C. The development of requirements for and configuration of an air purification system to remove contaminants produced by man, materials of construction, and chemical and microbiological reactions.
- D. The alteration of certain critical systems to allow for overboard venting if interactions went beyond the bounds allowed.

#### Criteria for Classifying Materials

1. Know ill effects on personnel from the same or similar formulation in aircraft systems. A typical example being the nausea reported by pilots using oxygen carried thru neoprene lines.
2. Known physiological compatibility. The success of silicone rubber implants and the completely non-allergenic nature of nylon indicate that these basic materials are probably not hazardous.
3. Knowledge of chemical composition and stability. A typical material of this type is Teflon. This polymer has a constant composition, i.e., it is not formulated with plasticizers, anti-oxidants, etc., and the thermal stability and toxicity have been thoroughly studied.
4. The presence or absence of odor under the actual environment to which the material will be exposed. Odor is a practical

though qualitative indication of the release of volatile contaminants. Odors may result from residual solvents, thermal degradation products, chemical reaction, sublimation of solid chemicals, or from desorption of gas adsorbed during an earlier environment.

5. Ultraviolet adsorption. The collection of a yellow, oily substance in the humidity underflow water in MESA I indicated a possible correlation between the optical density of a water extract and a potential contaminate source. Materials yielding optical densities higher than 10 were rejected on suspicion. For many commercial organic materials the formulation is unknown. The elimination of such questionable materials solved two problems. First the elimination of extensive laboratory testing and second, the problem of identifying what had been tested.

The detailed material changes resulting from the application of the criteria to the various systems are tabulated on the following pages.

AIR CONDITIONING SYSTEM				
COMPONENT	MATERIAL	LOCATION	TMAX °F	PROBLEM ACTION
Flexible Ducting	Neoprene - Same as resp. system.	Distribution duct to A/C system & to bunk outlets.	Ambient	Malodorous Replaced with sili-cone ducting.
Distribution ducts & heat exchanger.	Galv. Iron; aluminum & copper.	General	Ambient	Residual odors. Cleaned & Reused
Joint tape.	Adhesive backed glass fabric.	Duct joints (external)	Ambient	Residual odors. Removed & replaced.
Acoustic insulation.	Resin bonded fiberglass	Muffler (new for MESA II)	Ambient	Possibility of glass fibers & resin being entrained in air stream. Enveloped in 1 mil. mylar, edges heat sealed with solvent-free adhesive.
Gaskets	Elastomeric sheet.	Flanged transition sections.	Ambient	Base stock could not be identified. Replaced with sili-cone sheet.
LITHIUM HYDROXIDE SYSTEM				
Particulate filters.	"Dust stop" as in respiratory system.	Outlet	Ambient	Possibility of vaporizing organic mercury compounds & sulfonated oil. Replaced with pyrex wool filtering fiber.
Cabinet	Plywood	Exterior surfaces.	Ambient	Continuous source of volatile organics less steel. Replaced with stain-
Seal & Adhesive	Natural rubber foam & reclaim. rubber.	Between door & cabinet.	Ambient	Foam had unpleasant odor. No data on formulation of adhesive. Replaced seal with silicone extrusion; adhesive with room temp. vulcanizing silicone (RTV-501)

RESPIRATORY SYSTEM					
COMPONENT	MATERIAL	LOCATION	T <sub>MAX</sub> °F	PROBLEM	ACTION
"Dust stop" particulate filters.	Glass fiber phenolic resin, sulfonated petroleum oil 0.01% phenyl mercuroic acetate 0.005% hexachlorophene.	Silica gel beds & NaO <sub>2</sub> bed outlets.	250 °F	Volatility of organic mercury compounds, oil & resin. (Not intended for use above 110 °F.)	Replaced with Pyrex wool filtering fiber. (Glass; no organics)
Silica gel	SiO <sub>2</sub> + Contam.	Dryer beds.	250 °F	Contaminated in previous runs.	Replaced with virgin silica gel.
Gasket	Neoprene elastomer.	Dryer beds.	250 °F	No data on formulation.	Replaced with silicone elastomer.
Flexible ducting	Neoprene glass fabric steel wire.	Dryer beds to heater to NaO <sub>2</sub> beds & to air conditioning duct.	300 °F	Very malodorous.	Replaced with silicone ducting.
Bonded honeycomb & perforated sht.	Aluminum	NaO <sub>2</sub> beds.	240 °F	Not compatible with NaO <sub>2</sub> + H <sub>2</sub> O; releases H <sub>2</sub> .	Replaced with stainless steel.
Sealant	Polysulphide liquid polymer.	NaO <sub>2</sub> beds.	240 °F	Not known whether compatible with NaO <sub>2</sub>	Replaced with Q-felt
Thermocouple lead wire insulation.	Nylon glass served.	NaO <sub>2</sub> beds.	240 °F	As above.	Isolated with glass tubing.

# WATER SYSTEM

COMPONENT	MATERIAL	LOCATION	T MAX °F	PROBLEM	ACTION
Electrical insulation.	Plasticized poly-vinyl chloride (PVC) sleeving.	Electrical leads to catalytic oxidizer heater & evaporator.	Intended to be ambient; accidentally above 450°F	Plasticizer was tri-cresyl phosphate. This & HCl released on thermal decomposition of PVC are undesirable.	Replaced plastic with ceramic in all locations where temperature could possibly exceed ambient. Removed all TCP plasticized sleeving.
Thermal insulation.	Resin bonded rock wool.	Evaporator	225	Malodorous at use temperature.	Replaced with Q-felt.
Nuts & bolts.	Cadmium plated steel.	Flange on catalytic oxidizer assy.	1100	Known volatility of cadmium & known toxicity of cadmium vapors.	Replaced with stainless steel.
Cabinet	Plywood	Panels	Ambient	Source of natural & adsorbed organics.	Replaced with metal.

# FOOD PREPARATION CABINET

Door liner.	Cotton fabric reinforced phenol-formaldehyde resin (formica).	Inner face of cabinet door.	165	Phenolic odor at 165°F.	Replaced with aluminum foil-covered, asbestos-reinforced hydraulic cement board (Transite).
Seal	Elastomer	Between door & cabinet.	165	Unknown composition	Silicone extrusion.
Cabinet	Plywood	Panels	Ambient	Source of natural & adsorbed organics.	Replaced with metal.

# WASTE TREATMENT SYSTEM

Cabinet	Plywood	Side panels, equipment supports, toilet booth.	"	"	"
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COMMAND CONSOLE					
COMPONENT	MATERIAL	LOCATION	TMAX °F	PROBLEM	ACTION
Cabinet	Plywood	Side & display panels.	Ambient	Source of natural & adsorbed organics.	Replaced with metal.
PERSONAL HYGIENE CABINET					
Cabinet	Plywood	Side, back & top panels.	"	"	"

# AIR PURIFICATION SYSTEM

COMPONENT	MATERIAL	LOCATION	T <sub>MAX</sub> °F	PROBLEM	ACTION
Catalyst	Hopcalite	Hopcalite unit.	750°	Contaminated with NH <sub>3</sub> , NO & Freon; see P. 39 for details.	Replaced with new opcalite.
Gasketing	Nitrile rubber bonded asbestos sheet packing.	Flanges in Hopcalite & heater assembly.	750° F	Obnoxious odors at elevated temperatures.	Gaskets heated with acetylene torch until all organics removed prior to installation.
Nuts & bolts.	Cad. plated steel	Flanges in hopcalite & heater assy.	750° F	Known volatility of cadmium & known toxicity of cadmium vapors.	Replaced with stainless steel.
Thermal insulation.	Organic sized asbestos tape.	Hopcalite & heater assy.	750° F	Material scorched & evolved fumes at operating temp.	Replaced with Q-felt calcined at 1000° F & glass cloth cover baked at 450° F to remove weaving lubricant.
Particulate filter.	Mine Safety Appliances Co. (MSA) honeycomb-type ultra aire filter CU-82179.	Cabin air inlet to Hopcalite unit.	Ambient	Disinfectant odor (cresylic type).	Removed - not required.
A. V. BOOTH					
Cabinet	Plywood	Interior & exterior surfaces	Ambient	Source of natural & adsorbed organics.	Replaced with plaster board.
Seal & Adhesive	Foam rubber & reclaimed rubber adhesive.	Between door & cabinet face.	Ambient	Foam rubber had unpleasant odor; adhesive composition unknown.	Replaced with silicone cone extrusion & RTV adhesive.
Fluorescent Lamp		CFF testing unit.	Approx. ambient.	Toxic nature of certain phosphors used in such lamps (beryllium silicates)	Configuration changed to protect lamp from breakage in event of mechanical failure.

FURNISHINGS & TEST BED					
COMPONENT	MATERIAL	LOCATION	T <sup>F</sup> <sub>MAX</sub>	PROBLEM	ACTION
Shelves, cabinets, flooring, bunks.	Plywood		Ambient	Source of natural & adsorbed organics.	Replaced with metal.
Floor covering.	Composition tile & mastic adhesive.	Chamber floor.	Ambient	Unknown composition.	Replaced with continuous filament nylon carpet with a cotton back & without dye, tuft binder or jute backing.
Mattresses & pillows.	Polyurethane foam.	Bunk	Ambient	Malodorous due to contaminants adsorbed in MESA I.	Discarded. Replaced with new.
Drapes	Cotton	Bunks	Ambient	Retained odors.	Laundered.
Sleeping Bags	Cotton, nylon & dacron.	Bunks	Ambient	Retained odors.	Dry cleaned & pumped down to remove traces of cleaning solvent.
Surface coating.	Paint	Test bed inner surfaces.	Ambient	Extract produced high U.V. optical density.	Removed by sand-blasting all surfaces.

The development of the air purification system for MESA II was based on a very conservative engineering philosophy. The design objective was to completely remove all airborne contaminants as rapidly as they were generated and to accomplish this with proven components. The first objective dictated a requirement for the massive transport air through a high efficiency prime purification unit. The second indicated that sodium superoxide could not be considered as a prime material for maintaining a contaminant free atmosphere. Since the actual identity of the possible contaminants could not be defined, the selection of proven components had to be based on efficiency and versatility in other applications. For these reasons it was determined that the basic air purification unit should meet as a minimum, the United States Air Force Ballistic Missile Division specification requirements for filters for underground launch sites. It was also determined that this filter should be large enough to handle the entire air flow of the Air Conditioning System (600 CFM).

The unit selected for this purpose was a Mine Safety Appliance Company, Chemical-Biological, Radiological (CBR) filter #CU-8240 with a capacity of 1000 SCFM. The unit consists of three major components:

- 1) A steel frame to hold the filter elements.
- 2) A MSA Ultra Aire Space Filter element for particulate matter.
- 3) Chemical element for gaseous matter.

The entire assembly measures 24" x 24" by 22 1/4" deep.

The Ultra Aire Filter is a self-supporting "honeycomb" type fabricated by pleating a continuous sheet of an all glass microfiber, water resistant medium. Each filter element is individually tested with 0.3 microw particles of di-octyl phthalate in accordance with Chemical Corps Standard MIL-STD-282 and certified to be a minimum of 99.97% efficient.

The chemical element is folded, perforated steel sheet designed to hold approximately 43 pounds of activated coconut-base charcoal in a uniform bed depth of 3/4 inch. The charcoal is "iodized" with 4% potassium iodine and 2% iodine to improve the effectiveness against inorganic acid gases.

Performance Data at rated flow (1000 CFM) (Minimum time for first penetration at 300 PPM feed)

GAS	Specification Requirement	M.S.A. TEST DATA (Typical)
	MINUTES	MINUTES
CCl <sub>4</sub>	60	190-270
Cl <sub>2</sub>	20	20-22
SO <sub>2</sub>	15	14-15
CCl <sub>4</sub>	--	65-75

Tested in Sequence  
on same filter.

The CBR filter was located at the inlet to the air conditioning system. The operation at less than rated flow rate increased the residence time of the air in the filter and thus provided potential for improved performance.

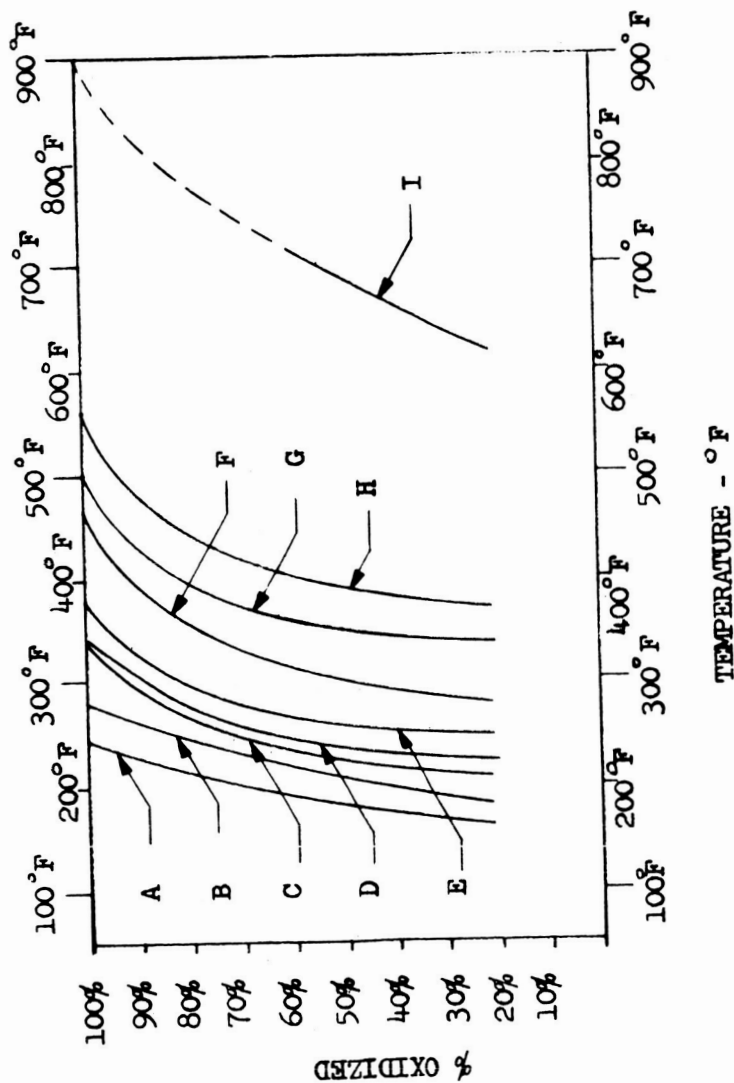
The incorporation of the CBR filter did not satisfy all of the requirements for a trace contaminant free atmosphere. The inability of activated carbon to retain certain contaminants known to be produced by man and possibly by equipment imposed a need for an additional prime system. Carbon monoxide, hydrogen and methane, all major constituents in flatus, are typical contaminants which can not be controlled by carbon. Fortunately catalytic systems for the conversion of such gases to carbon dioxide and water have been well developed and proven in a wide variety of services. Hopcalite, a mixture of oxides of manganese and copper will quantitatively convert CO to CO<sub>2</sub> at temperatures as low as 0°F. Pioneering research effort by The Boeing Company and their subcontractor, the United States Bureau of Mines, Bruceton, Pennsylvania had established that Hopcalite, operated at high temperatures could catalyze the oxidation of extremely refractory high molecular weight organic compounds (diester lubricating oils). Mine Safety Appliance Company working with The Boeing Company developed and qualified Hopcalite filter units to meet the requirements for the B-52 Airplane. They supplied units to outfit the entire B-52 fleet. Since that time numerous other Aircraft and submarine weapon systems have used high temperature Hopcalite Units for air purification. High temperature Hopcalite Units are also widely used industrially for the oxidation of trace hydrocarbons in air utilized for air liquefaction and separation and for hydrogen elimination.

The well established performance and versatility of this catalyst system justified its retention as a prime method of removing contaminants evolved from the waste system and for the removal of major flatus gases from the cabin air.

The selection of a proper operating temperature posed a dilemma which could be solved only by compromise. The dilemma resulted from conflicting requirements with respect to ammonia and methane. Boeing laboratory tests had indicated that between 650°F and 700°F, NH<sub>3</sub> an expected product from the waste reactor, was at least partially oxidized to NO<sub>2</sub> with increasing yields as the temperature was increased. Mine Safety Appliance Company data, Figure 12 disclosed that CH<sub>4</sub>, a product from flatus or an anaerobic reactor, required temperatures approaching 900°F for total oxidation and with very little conversion below 600°F. The selected operating temperature of 600°F was arrived at in the following manner:

- 1) It was found that NH<sub>3</sub> was effectively absorbed in moist indicating silica gel and reacted with the cobalt chloride indicator to form a deep blue color. The change from pink back to blue thus indicated the fraction of the bed which was saturated. Therefore a 2 1/4 inch diameter 20 in. long silica gel bed, enclosed in a transparent acrylic case, was incorporated into the waste reactor system between the condenser and the Hopcalite Unit. This bed was an element in the air purification system.

Ref: Data taken from M.S.A.  
Bulletin 1504-4, Technical  
Products Release Number 1501



HYDROCARBON CONVERSION M-S-A CATALYTIC FILTERS

Figure 12

- 2) Examination of the production rate of methane in flatus indicated that this gas would not reach a high enough concentration in 150 man days to be a problem if there were no other sources. However, if the waste reactor became anaerobic for any extensive time period the methane concentration could increase rapidly. Design and operational provisions were implemented to eliminate this source. Therefore, the extremely high temperature requirement for methane was removed.
- 3) The MSA data Figure 12 demonstrates that the other aliphatic hydrocarbons were completely oxidized below 600°F. It also demonstrates that unsaturation and increasing molecular weight generally decrease the temperature requirement.

The Hopcalite unit consisted of 6 basic elements:

- 1) A stainless steel case
- 2) Two Calrod heating elements wired in parallel - 950 watts each.
- 3) Two Hopcalite filter assemblies MSA #SM CV 66444 arranged in series
- 4) A chromel-alumel thermal element located between the two filter assemblies
- 5) A West Instrument Corporation Gardsman pyrometric controller
- 6) A stainless steel air to air heat exchanger.

The Hopcalite filter assemblies consisted of stainless steel frames and hardware cloth, glass scrim cloth, felted AA glass fiber (no binder) and the catalyst. Each assembly was 11 1/2 inches square and 1 3/4 inches deep and contained approximately 6 pounds of catalyst.

The pump delivered a room temperature flow to the unit of 9.5 CFM of which approximately 0.07 CFM came from the reactor and the balance from the cabin. The decrease in density of the air upon being heated to 600°F increased the volume flow to about 17.5 CFM across the beds. Thus at this condition the space velocity in the catalytic reactor was about 5000 reciprocal hours.

During the laboratory testing of the Hopcalite unit after MESA I, it was found that room air passed through heated unit acquired a very unpleasant odor. A review of the post MESA I chamber tests revealed that the Hopcalite Unit had been operating during a sampling period when a large volume of Freon had been released in the chamber. As it is well known that the Freons have an adverse effect on Hopcalite, new catalyst was obtained. The filter assemblies were unloaded, cleaned and repacked with all new materials.

Further testing of the system with the new catalyst revealed that NO<sub>2</sub> was evolved at temperatures as low as 345°F and concentrations of 40 to 50 ppm appeared at temperatures around 600°F. Since no

similar problem had ever been experienced with the B-52 filter units, Mine Safety Appliance Company was contacted and their assistance requested. They advised that a similar problem had come to their attention a few months before and had been the subject of considerable research. The cause had been identified as a batch of catalyst containing a small amount of ammonium nitrate which decomposed at elevated temperatures to yield  $\text{NO}_2$ . Their tracing showed that this contaminated catalyst had been used in the units supplied for MESA I and had inadvertently been supplied as the replacement material. They then delivered a catalyst from a non-contaminated batch. As a precautionary measure, they passed  $650^\circ\text{F}$  air through the Hopcalite for 24 hours at which time only a trace of  $\text{NO}_2$  could be detected. Boeing laboratory tests utilizing a tube furnace and scaled air flow, on this batch showed no  $\text{NO}_2$  below  $437^\circ\text{F}$ , 0.1 ppm at  $520^\circ\text{F}$  and 1.0 ppm at  $600^\circ\text{F}$ .

$\text{NO}_2$  could also arise from the equilibrium reactions,  
 $\text{N}_2 + \text{O}_2 \rightleftharpoons 2\text{NO}$  (Equilibrium data is shown in Figure 13 ).  
and  $2\text{NO} + \text{O}_2 \rightleftharpoons 2\text{NO}_2$ .

The approach to equilibrium is dependent on flow rate, catalytic efficiency and the quenching rate and therefore the configuration. It was concluded that the actual unit must be tested. The filter assemblies were repacked with the new Hopcalite and the entire unit was reassembled. Testing revealed no detectable  $\text{NO}_2$  at  $600^\circ\text{F}$  and the processed air had a very clean odor.

At approximately the same time period, it was discovered that the waste reactor was also a source of  $\text{NO}_2$ . Under highly aerobic conditions the pH dropped and organic nitrogen was converted to  $\text{NO}_2$  rather than  $\text{NH}_3$ .  $\text{NO}_2$  gas was introduced into the effluent air stream under these conditions. Laboratory tests showed that the silica gel bed introduced for the control of ammonia was also effective against  $\text{NO}_2$ . Further tests showed that  $\text{NO}_2$  could be captured in the sodium superoxide. Since the water systems, another known source of  $\text{NO}_2$ , had been vented overboard, it was concluded that  $\text{NO}_2$  could be controlled.

An auxiliary portion of the air purification system related to the waste system was an activated carbon filter located downstream of the Hopcalite unit. This unit consisted of an aluminum case, an unbonded glass fibre particulate filter and Pittsburgh Chemical Company's PCB coconut nut shell base activated carbon. The bed was 16 inches long  $3\frac{3}{4}$  inches wide and 6 inches deep. Experiment showed that at temperature of  $200^\circ\text{F}$  and higher, air reacted with the carbon to produce CO. Although this was approximately  $40^\circ$  higher than the outlet temperature of the Hopcalite it was decided to separate the two units with about 12 feet of aluminum ducting. This brought the air temperature down to approximately ambient ( $75^\circ\text{F}$ ).



# EQUILIBRIUM DATA

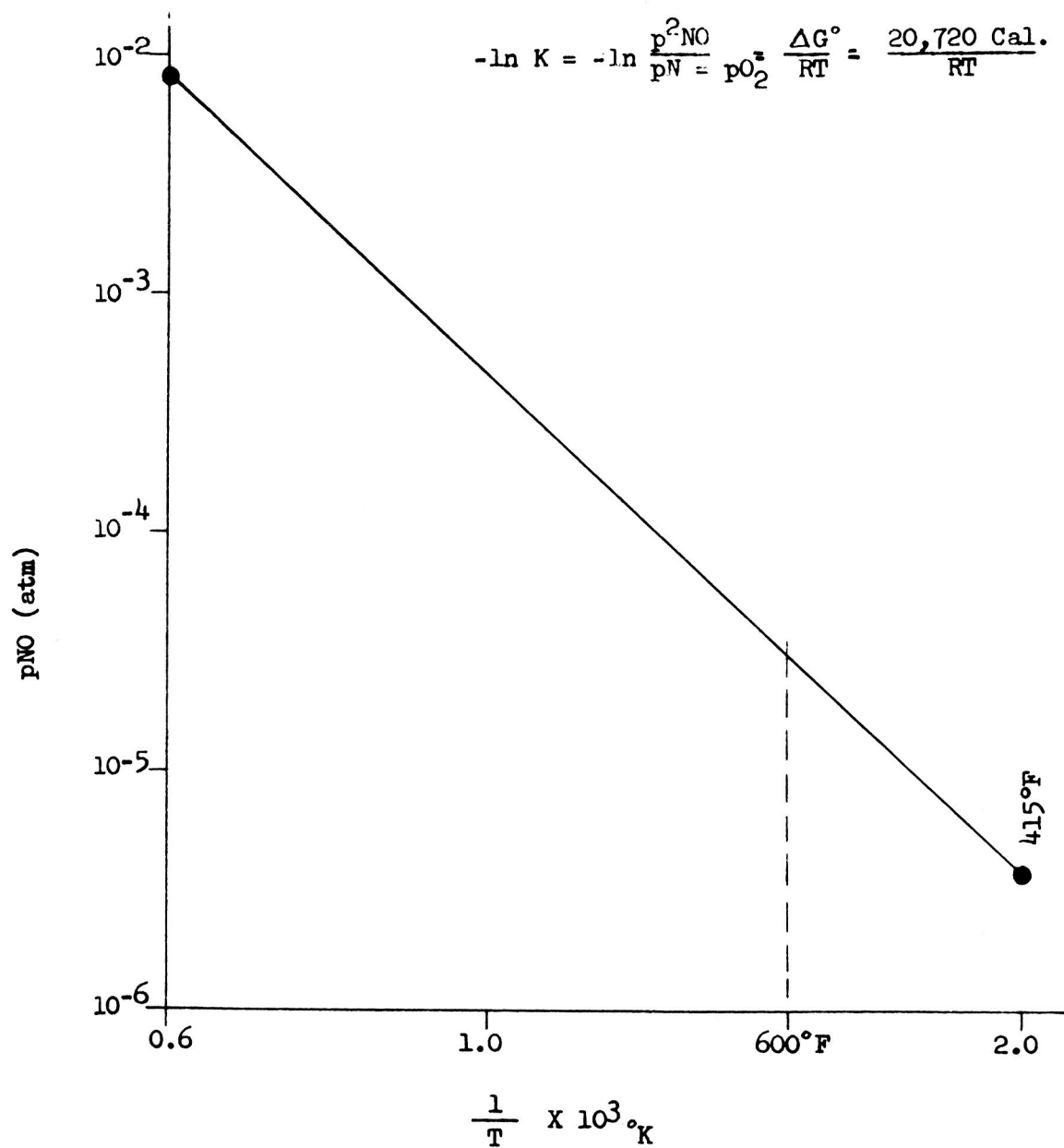
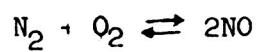


FIG. 13

The Ultra-Violet lights installed for the control of airborne micro-organisms in MESA I were retained as components of the air purification system. The incorporation of the CBR was expected to essentially remove any requirement for these units. However, it was desired to obtain information on their performance if possible.

A charcoal filter was installed in the command console. This unit was intended to remove contaminants which might be placed in the consoles cooling air by overheated electrical insulations. The bed was 9 inches long, 7 3/4 inches wide and 3 3/4 inches deep. It contained an unbonded fiber glass particulate filter and PCB activated carbon. The flow through the unit was estimated as 110 CFM.

The remaining component specifically included for the control of trace contaminants was a silica gel filter installed in the foam separator seal vent line of the water system. Its purpose was to prevent  $\text{NH}_3$  from being transported to the Hopcalite unit in the event of seal leakage. The unit was 2 1/4 inches in diameter and 20 inches long.

Several elements of the other subsystems contributed to air purification as a secondary function.

The metabolic water condenser allowed an opportunity for scrubbing water soluble gases from the entire air conditioning flow. Prediction of the purification performance could not be made without knowledge of the nature and concentration of gases passing through the CBR filter.

The silica gel drying beds in the respiratory systems had demonstrated in MESA I that they had the capability of acquiring and retaining organic contaminants. Again no performance prediction was possible without knowledge of contaminants entering the driers.

The sodium superoxide and lithium hydroxide beds could be anticipated to effectively react with acid gases. Although oxidation of certain organic species by  $\text{NaO}_2$  might be hypothesized, there was inadequate data to substantiate this as a proven purification system.

The location of the components in the air purification system is shown in Figure 14 .

Provisions were made for the overboard venting of two systems which were critical sources of contaminants. Post MESA I tests showed that high concentrations of  $\text{NO}_2$  existed in the exhaust air stream from the air-water phase separator. This product was formed from the oxidation of  $\text{NH}_3$  in the 1100°F platinized aluminum catalyst bed. To eliminate this source, the system was provided with two small high pressure oxygen bottles to be used in place of cabin air and a continuous overboard vent.

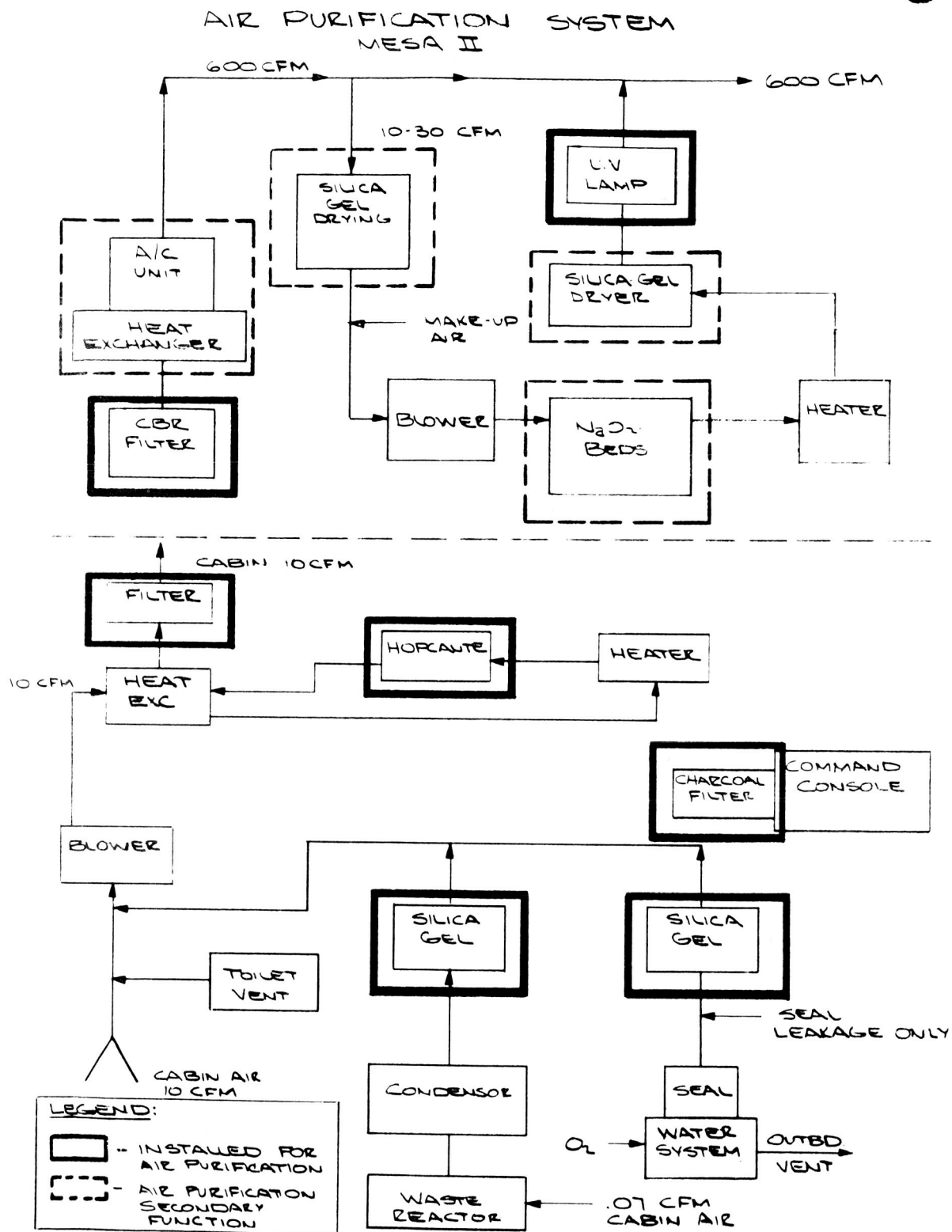


FIG. 14

The waste system was equipped with a provisional external air supply and overboard vent. The purpose of this modification was two-fold. In the event the reactor became anaerobic it could be expected to produce up to 3 cubic feet of methane a day and significant amounts of hydrogen sulphide. There was no portion of the air purification system designed to remove methane and poisoning of the Hopcalite catalyst by excessive hydrogen sulphide was a possibility. On the other hand if the systems became too highly aerobic and the production of the  $\text{NO}_2$  could not be controlled the concentration of this gas might become significant. Thus the overboard system provided for control in both the anaerobic and hyperaerobic condition.

In summary, the trace contaminant management program attempted to provide an atmosphere free of toxic substances by:

- A. Elimination of material sources of contaminants
- B. Air purification utilizing proven concepts and equipment
- C. Design changes to decrease the contamination problems arising from the processing of human wastes.

## SYSTEMS TESTS

### A. 17 Day Integration Test

Data on the performance of the system was acquired by measuring concentrations of various gases at the stations identified on Figure 47 ; chemical analysis of water samples from the humidity underflow system, and subjectively, by odor.

A special test configuration in which the CBR filter was removed from the system was included for a specific evaluation of this unit. Other special conditions involved the overboard venting of the reactor and modifications to the temperature setting for the Hopcalite unit.

From a subjective standpoint the performance of the system with all units operating was excellent. There were three identifiable pieces of equipment which produced odors:

- 1) The organic finish on the air conditioning blower motor. This was a new motor with a 60 C temperature rise. When the case was hot a distinct odor of drying oil was emitted. The odor could only be detected in very close proximity to the motor.
- 2) A faint "hot metal" odor permeated the insulation on the Hopcalite unit. This could only be detected with the nose virtually in contact with the insulation's cover. This odor disappeared in a short time.
- 3) Hydrogen sulphide was noticed at the clean water tank on the shower system during the manned portion of the test. This probably came from anaerobic bacterial action on skin wastes. The hydrogen sulphide could be sensed only near the source even though it can be detected by odor in very minute concentration.

Odors were present for short periods of time following accidental effluent spills at the water system.

Alcohol odors were present for short time periods when the 70% alcohol used for sterilization of components of the water system was being drained from the systems.

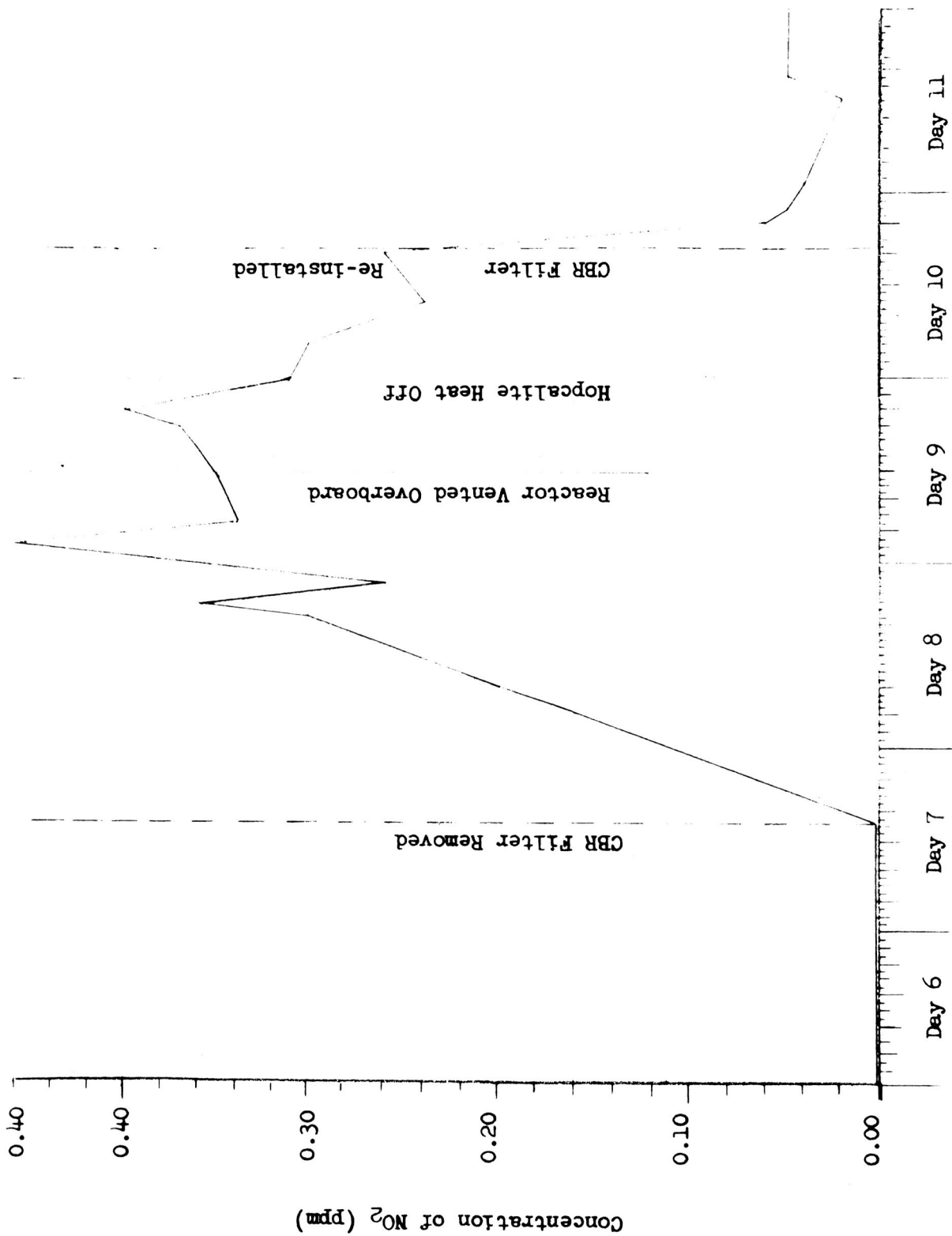
Prior to the manned portion of the test the only significant contaminant peak appearing on the gas chromatograph of the cabin air (Station 1) was identified as ethyl alcohol.

The chemical analysis of the humidity underflow water at all times revealed the presence of oxidizable chemicals (presumed to be organic) and  $\text{NO}_2$ . Thus some chemical species were apparently passing through the CBR filter. During day 3 it was discovered condensate that collected in the drop pan was not separated from water condensed from air processed by the CBR filter. Therefore, the concentration of organics and  $\text{NO}_2$  in the humidity underflow water did not truly represent the purification resulting from the CBR filter. The two condensates were physically separated, sampled and identified. This separation did not eliminate the chemical oxygen demand (COD) and the  $\text{NO}_2$  in the CBR condensate. However, a significant concentration difference between these two condensates was evident.

During day 7 of the test, the planned configuration change, i.e., the removal of the CBR filter from the air purification system was accomplished. After a very short period of time (3 hours) a crew member from MESA I reported that the odor in the chamber was just like MESA I but without the sweet smell." This odor was recognized as  $\text{NO}_2$  by a chemist. Concentration measurement with a Kittigawa detector tube indicated 0.15 ppm  $\text{NO}_2$  in the cabin air at this time. An intensive program of chemical sampling of the air from various stations to identify sources and concentrations was conducted. A similar program of frequent sampling and chemical analysis of condensate water was carried out. As shown in Figure 15a the concentration in the cabin air rose rapidly to a equilibrium value of approximately 0.35 ppm with a single maximum of 0.47 and a minimum of 0.20.

The air flowing out of the Hopcalite unit contained  $\text{NO}_2$  from the cabin and all other known sources; i.e. the waste reactor and the Hopcalite unit itself. Examination of the data from test day 9 showed that the average concentration at this station was 0.62 ppm. The average concentration of the cabin air entering the unit was 0.36 ppm. Thus the air contribution from this source was 0.25 ppm for the day. Converting this concentration into equivalent mg/liter of air and multiplying by the volume flow in liters/min. and the number of minutes in a day indicated a total addition to the atmosphere of 200 mg of  $\text{NO}_2$ .

During this same time period the water condensed in the humidity underflow system had an average concentration of 78 mg  $\text{NO}_2$ /liter of water. Approximately 4.15 liters of water were condensed in this day. Thus the water collected 320 mg of  $\text{NO}_2$  or 160% of that produced by the known sources. The additional source is hypothesized to be nitrogen fixation in the hydrogen flame which was being utilized for simulating the metabolism of 4 men. The hydrogen was being burned in an air rich Bunsen type burner. The equilibrium data for the  $\text{N}_2 + \text{O}_2 \rightleftharpoons 2 \text{NO}$  reaction, Figure 13 indicate that this reaction is thermodynamically feasible. The approach to equilibrium values would be dependent on the kinetic parameters such as flow rate, residence time, quench rate and possible catalysis.



CABIN AIR NO<sub>2</sub> CONCENTRATION SYSTEMS INTEGRATION

MESA II

Figure 15a

The effectiveness of the humidity underflow system removal of water soluble contaminants was well demonstrated by the acquisition of  $\text{NO}_2$ . The 320 mg. of  $\text{NO}_2$  removed would have increased the cabin concentration by 2.6 ppm/day.

The silica gel filter located downstream of the waste reactor removed between 50% and 97% of the  $\text{NO}_2$  delivered to it. It was most effective at high concentrations. This unit thus proved of great value in this application.

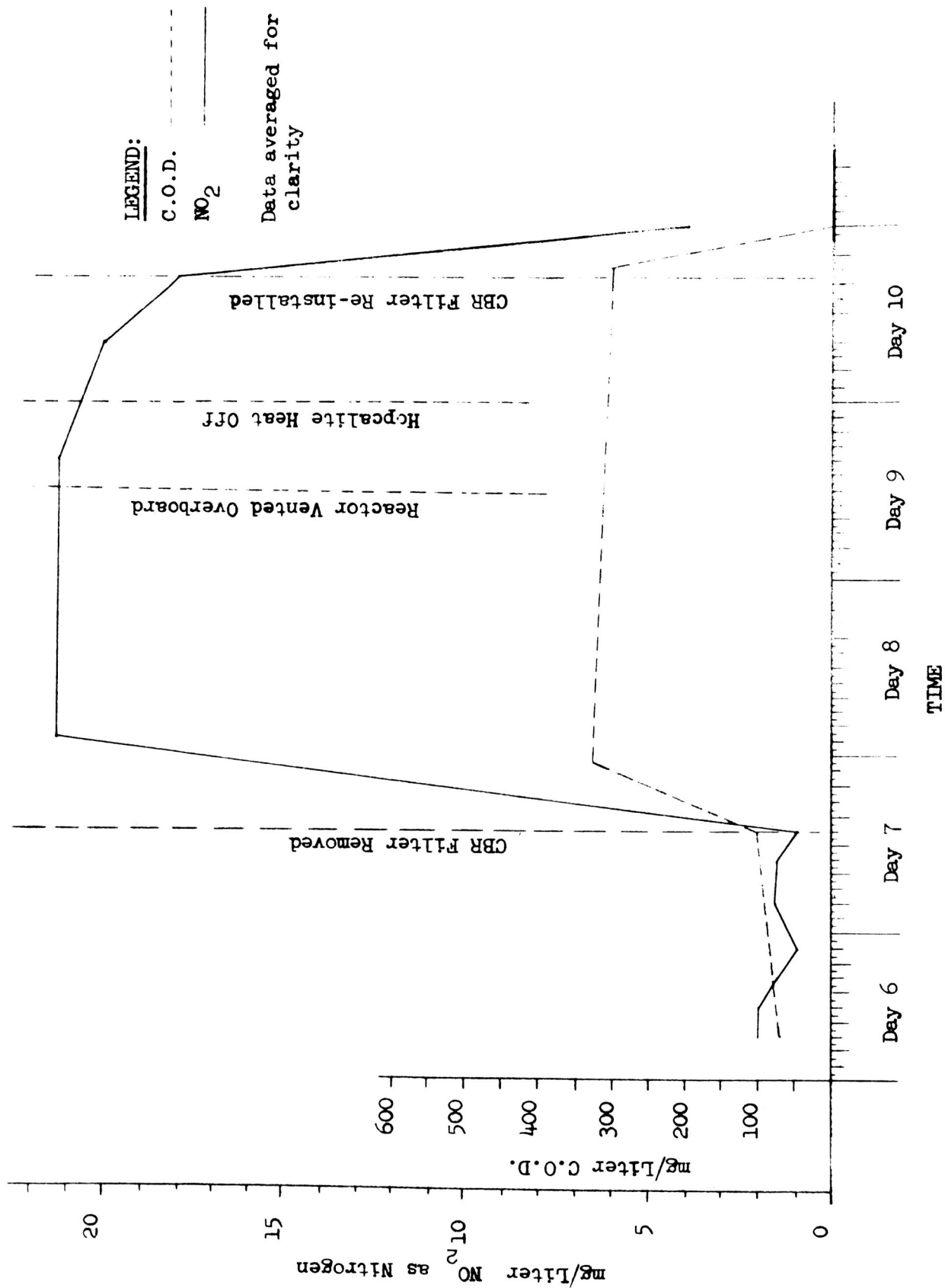
The increase in  $\text{NO}_2$  across the Hopcalite unit must be credited to catalytic oxidation of elemental nitrogen. The location of the thermal sensing element between the beds, the high capacity heaters, and efficient heat exchanger led to a high thermal lag in the system. This resulted in maximum temperatures of 750 F and minimums of 520°F on a 600°F setting. Previous lab tests had indicated that  $\text{NO}_2$  appeared above 650°F and disappeared below 550°F. This led to the deactivation of one heater (950 watts) on day 11 of the test. This decreased the temperature range to between 650°F and 540°F.  $\text{NO}_2$  production was still noted in the high temperature range. A final configuration and operational change was made on day 13. The two heaters were connected in series thus lowering the power to 475 watts, and a setting of 500°F was established. With this configuration the temperature cycled between 420°F and 503°F.

On day 10 the Hocalite heater was shut off but the blower was left operating. As the temperature dropped the catalyst either adsorbed or decomposed  $\text{NO}_2$ . The processed air concentration was only 16% of the inlet air. This effect is shown by the resulting decrease in cabin concentration in Figure 15b.

The CBR filter was reinstalled on day 10. The rapid reduction in both  $\text{NO}_2$  concentration and C.O.D. of the humidity underflow water was dramatic evidence of the capability of this unit to control both organic and acid contaminants. Prior to this time there was no available data on the performance of such a unit with  $\text{NO}_2$ . Since activated charcoal shows little retention for this gas the result must arise from reaction with the iodizing chemicals. Figure 15b.

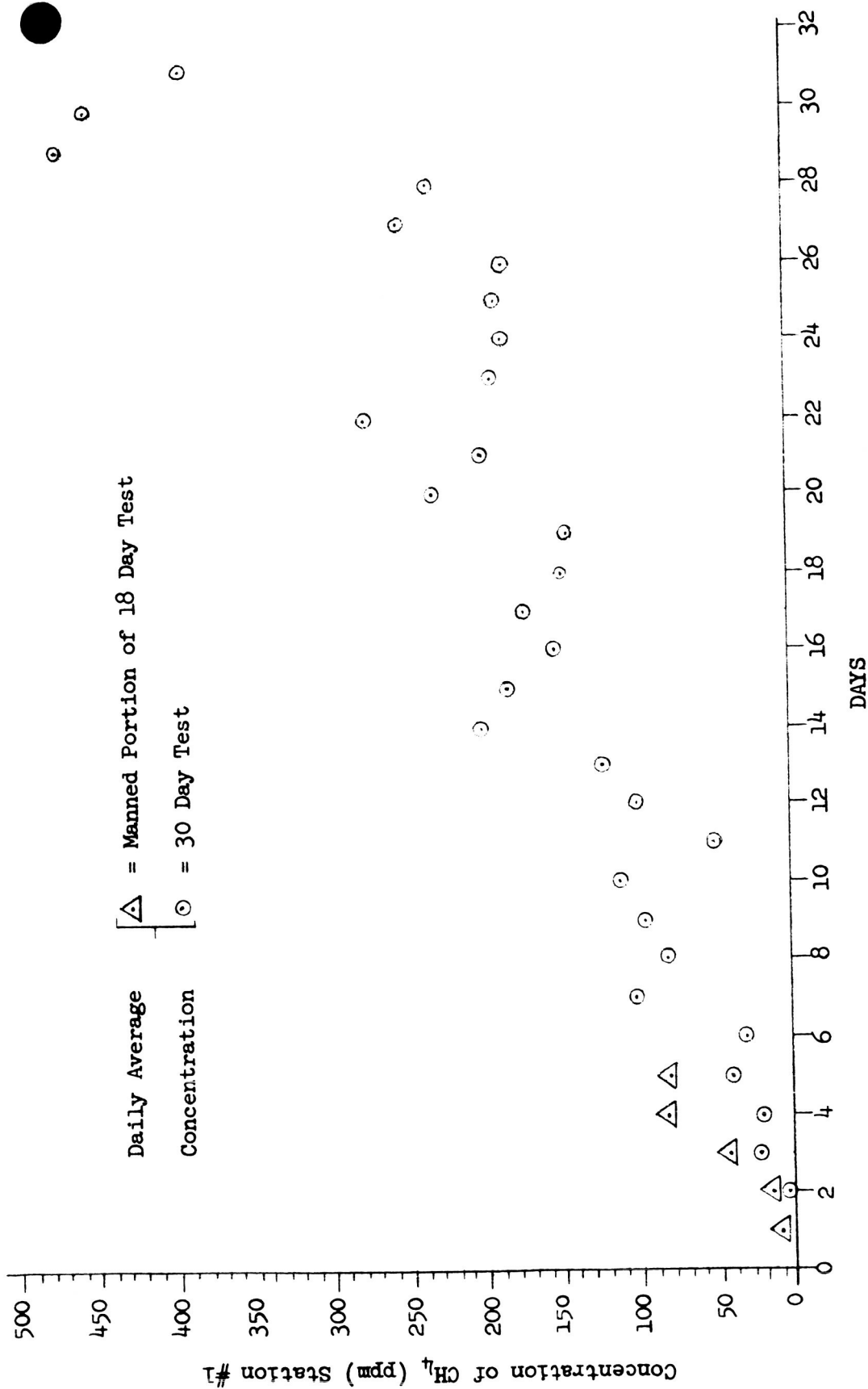
Three "contamination events" occurred during the 4 day manned run. One was the rapid build up of methane shown on Figure 16. The high production rate was probably due to a normal diet. On day 16 a strange odor was reported by crew members. A chemist entered the chamber and noted the odor immediately upon entering the air lock. The odor was not evident in the living or sleeping quarters. Careful "sniffing" revealed the source as an open container of medicated foot powder (Desenex) on a shelf in the first aid room. This was located directly in the draft of an air vent. Removal of the can from the chamber eliminated the odor. During the last day of the test one of the crew members noted a "rotten egg" odor in the vicinity of the shower water sterilization tank. This was identified after the test was completed as hydrogen sulphide. The source was





CONTAMINANT CONCENTRATION IN HUMIDITY CONDENSATE  
SYSTEM INTEGRATION TEST - MESA II

Fig. 15b



CABIN METHANE CONCENTRATION - MESA II

Fig. 16

presumed to be anerobic bacterial action on wastes from the skin. This was believed due to long time storage of the charcoal cartridge in a wet condition. The charcoal had not been sterilized and acted as a bacterial host. To eliminate this as a problem in the 30 day test a procedure was implemented for sterilization and for use of an overboard system if required.

At the conclusion of the test, various elements of the systems were removed inspected and replaced or repacked. The respiratory silica gel filters showed a yellow color on both the top and the bottom of the beds. This demonstrated that these beds did capture and return foreign substances in the air. The fact that no discoloration could be found in the humidity underflow water suggests that chemical changes producing chromophore groups occurred in the beds themselves. The beds were emptied and repacked with virgin silica gel.

Both the particulate and chemical filters in the CBR unit were replaced. A spare chemical filter was tightly packaged in Mylar and placed in the chamber as a replacement if required.

The Hopcalite unit was inspected, found to be in good condition and replaced.

The activated carbon bed downstream of the Hopcalite unit and the one in the command console were repacked and replaced.

B. 30-Day Manned Test

The performance of the air purification system was excellent. The air was maintained very free from odors and particulate matter. The crew members all reported the development of a hypersensitive olfactory response in a very short period of time.

The data in Section 6.2.2 demonstrates the effectiveness of the various elements in the system in the control of airborne bacteria. The CBR filter performed up to expectation, the sampling never showing more than one micro-organism in 30 cubic feet of filtered air. The Hopcalite unit was completely effective. The performance of the ultra-violet lights processing the effluent air from the respiratory system was difficult to assess due to the prior purification. Day 9 was the only sampling date on which an adequate concentration of organisms entered the light system to provide significant results. The count was reduced from 0.9 per cubic foot to 0.1 per cubic feet.

The environmental monitoring gas chromatograph did not indicate the presence of any contaminant in the cabin air other than alcohol and methane. The methane build-up Figure 16, was at a lower rate than during the 4-day test. This was probably due to the low gas producing diet. The source of alcohol was from sterilization.

The maximum  $\text{NO}_2$  level measured in the cabin air was 0.1 ppm although the waste reactor at times produced over 100 ppm. The high concentrations were in very low volume flow air streams, .07 CFM. Significant reduction in this concentration was accomplished by the silica gel. The  $\text{NO}_2$  which entered the cabin air was controlled by the CBR filter and the humidity condensate.

As in the 17-day test, a significant C.O.D. was evident in the humidity underflow water condensed from the filtered air as shown in Figure 17. By Day 8 the average C.O.D. value had built up to a near equilibrium value of 260 mg/liter. The average daily values varied from a maximum of 315 to a minimum of 195 through the first 23 days. The concentration suddenly increased on Day 24 to a maximum of 760. A spill of 8 ounces of alcohol in the chamber immediately before this rise was suspected as the cause. The system was completely drained the next day to allow fresh condensate samples to be taken. There was no significant decrease in the C.O.D. of samples collected after drainage. It was concluded that the C.B.R. chemical element had reached saturation with respect to the contaminants causing the C.O.D. The chemical element was removed and the spare installed in its place. The C.O.D. rapidly dropped to about 120 and remained at this value through the rest of the test. The 41 pounds of activated carbon in the original unit had an effective life, under the test conditions, of 115 man/days.

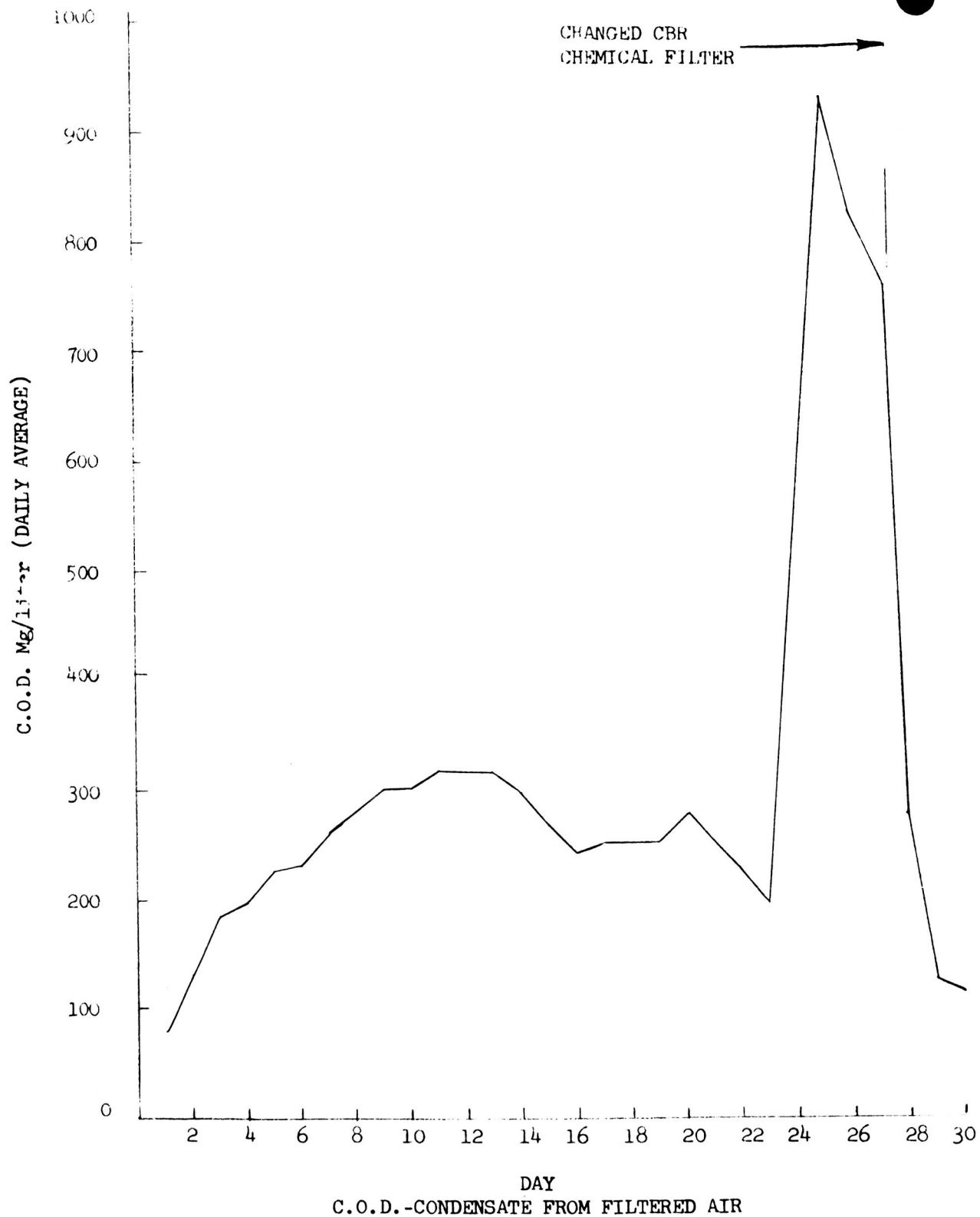


FIGURE 17

The data in Section 6.2.1 relating to concentrated samples indicates the presence of numerous chemical species in the atmosphere. The concentrations of these foreign materials was maintained at such a low level that normal continuous monitoring failed to indicate their presence. Which of these contaminants penetrated the C.B.R. filter throughout the test and led to its eventual saturation is not known.

Section 6.2.1 also presents data on a concentrated sample collected at the external vent line of the water system. Peaks not found elsewhere indicate that this system would have contributed significantly to the contamination problem had it not been vented overboard. The water system did supply contaminants to the atmosphere during several short periods during the test. This occurred from effluent spills, broken sight glasses, and removal of the defoamer assembly for the replacement of bearings and seals.

Peaks found in the waste reactor samples and not in the cabin air demonstrate the effectiveness of the silica gel bed and the Hopcalite unit in controlling contaminants from this source.

A contamination event arising from bacterial action occurred Day 4. A foul odor was noted near the personal hygiene cabinet. This was traced to the sump. The water had not been drained from the sump after the 4-day manned test. Bacterial growth occurred and microbial action degraded residual organic matter producing very evil odors. The system was cleaned and the plumbing changed so that the sump could be drained. The odors did not persist in the chambers.

At the conclusion of the 30 day test the silica gel beds from the respiratory system were inspected. The top of the beds were a dark amber color. The beds were fractionated using a suction tube into 4 fractions of different colors. As shown in photographs 1 and 2, the top 1/2 inch was very dark, the second 1/2 inch was yellow, the middle 4 inches were white and the bottom 3/4 inch was yellow. This again demonstrated the capability of the silica gel to remove contaminants. The top of the bed received the flow from the superoxide beds. The dark color at the top may therefore be due to chemical changes to contaminants passing through the beds or to this portion of the beds receiving maximum heat during the drying cycle.

#### 6.1.2.3 Recommendations

1. The requirement for ultra-violet lights for bacterial control appears to be unnecessary when large volume CBR filtration is used. The CBR particulate filter is polyfunctional and very lightweight. It is recommended that the ultra-violet system be eliminated.

2. The behavior of the MESA Hopcalite unit with respect to the formation of  $\text{NO}_2$  was unique. This is probably due to the relatively low space velocity, the low mass flow at high temperatures, and the configuration. This should be studied to arrive at a system which can operate at higher temperatures without an  $\text{NO}_2$  problem.
3. The high usage of carbon in the CBR chemical element, 0.4 pounds per man/day, is far in excess of commonly predicted requirements for space systems. This should be studied to determine if it is a realistic requirement. Methods of re-activation should be studied.
4. A "white" list of materials and associated environments suitable for use in manned closed systems should be prepared for design use. This should include specifications controlling the chemistry and processing variables as well as functional requirements.
5. Methods of improving the performance of the humidity condensate system with respect to the removal of trace contaminants should be studied.
6. Tests should be conducted on the various components of the air conditioning system using known chemicals to assess their performance. The chemicals should be selected from those anticipated in actual systems. Emphasis should be placed on those most difficult to remove and/or retain.

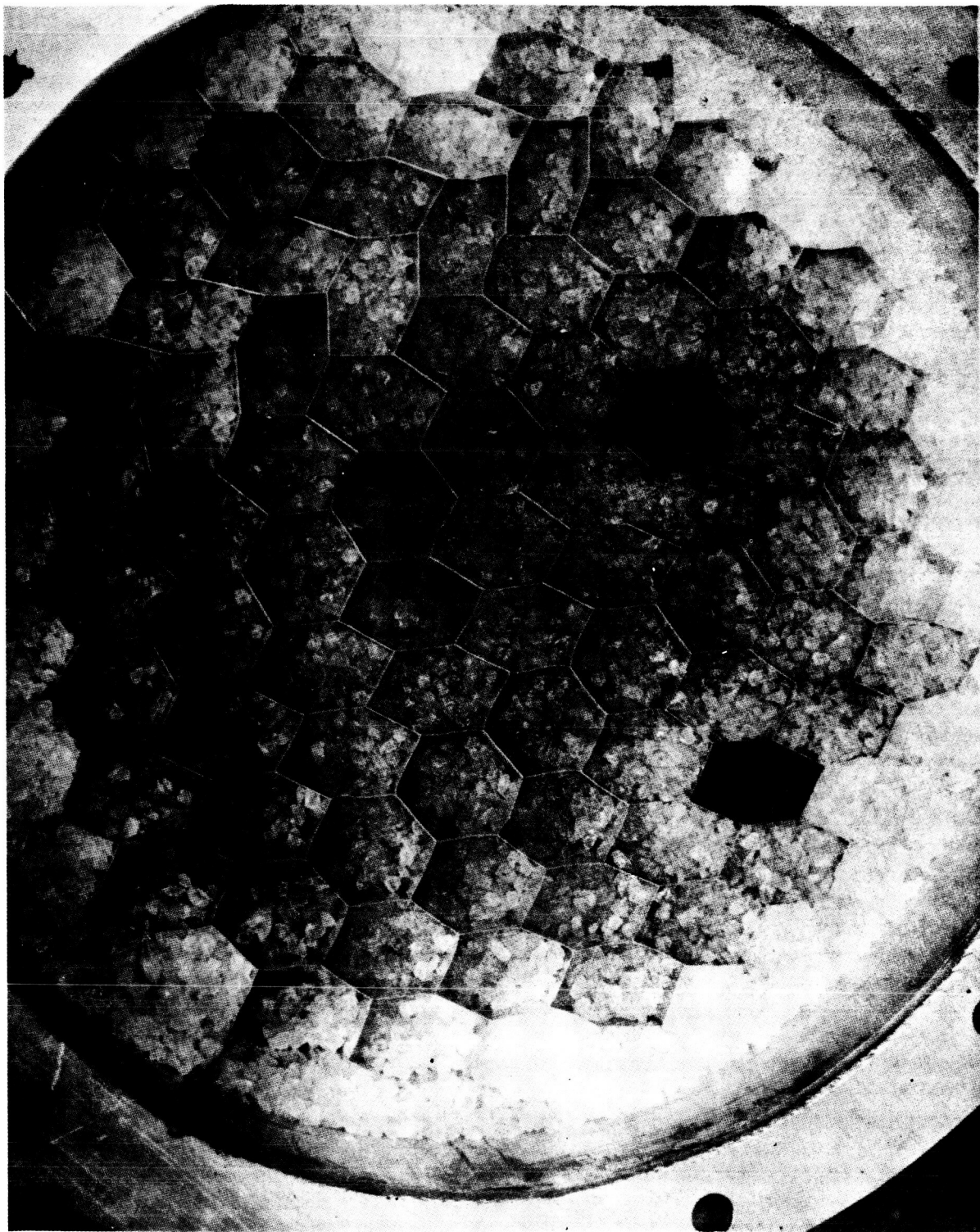


Photo 1: CONDITION OF SILICA GEL IN AIR DRIER AFTER 30 DAYS  
OPERATION — MESA II





Photo 2: CROSSSECTION SAMPLES OF SILICA GEL FROM RESPIRATORY SYSTEM DRIER AFTER 30 DAYS OPERATION

DEVELOPMENT

The waste disposal system shall provide for collection, transfer, storage, and treatment of urine, feces, and personal hygiene water from five men for thirty days. A Boeing-developed "Aerobic" biological "Activated Sludge" process was selected for this system. The culture from the waste reactor was centrifuged to produce supernatant for the water system to convert to potable water.

Calculations showed that a minimum volume of twelve liters per man of culture containing feces, urine, wash water and soap must be retained in the reactor at all times in order to preserve the microbiological population. The deposit rate of urine, feces and wash water was established as approximately 5 liters per man per day. In order to preserve the culture in the reactor in an aerobic state it was calculated that the following conditions must be met.

- A. Maintain the culture at 90°F.
- B. Aerate the culture by introducing air at a rate of not less than 1 CFM.
- C. Agitate the culture with a paddle wheel located inside the reactor tank rotating at 30 RPM.

The basic container was a stainless steel cylindrical tank with a total capacity of 87 liters.

A centrifuge capable of self cleaning was required in order to provide the supernatant for the water treatment system. (Batch centrifuging was not considered acceptable because of the manual clean-up required). The cells remaining after centrifuging were returned by pump to the reactor.

Analysis showed that when the system was "Aerobic" the reactor exhaust gases contained principally  $\text{NO}_2$ ,  $\text{CO}_2$  and  $\text{NH}_3$ . It was theoretically determined that these exhaust gases would be absorbed by a charcoal filter and the  $\text{NaO}_2$  beds. Accordingly, a dehumidifier to control the relative humidity of the exhaust gas to  $50\% \pm 5\%$ , a charcoal filter and the necessary neoprene ducting to the  $\text{NaO}_2$  beds were provided. In addition, a 20 mesh stainless steel filter screen was added to the exhaust line just above the tank top. This screen prevented any solid matter from being carried out in the exhaust air stream.

The feces receiver unit was made from an anodized aluminum cylinder containing a seat and a manually operated slide valve

at the top of the cylinder. An electrically operated grinding unit (household sink disposal unit) was attached to the bottom of the cylinder for comminuting solids. In order to dilute the waste and wash the cylinder one liter of water was introduced into the toilet from a plexiglass holding tank after each use. Urine was collected separately in individual plastic horns and then drained into a measuring container before deposit in the reactor. Odor control was achieved by air flow of four CFM through the toilet and into the reactor. A peristaltic pump was used for moving both air and comminuted waste to the reactor.

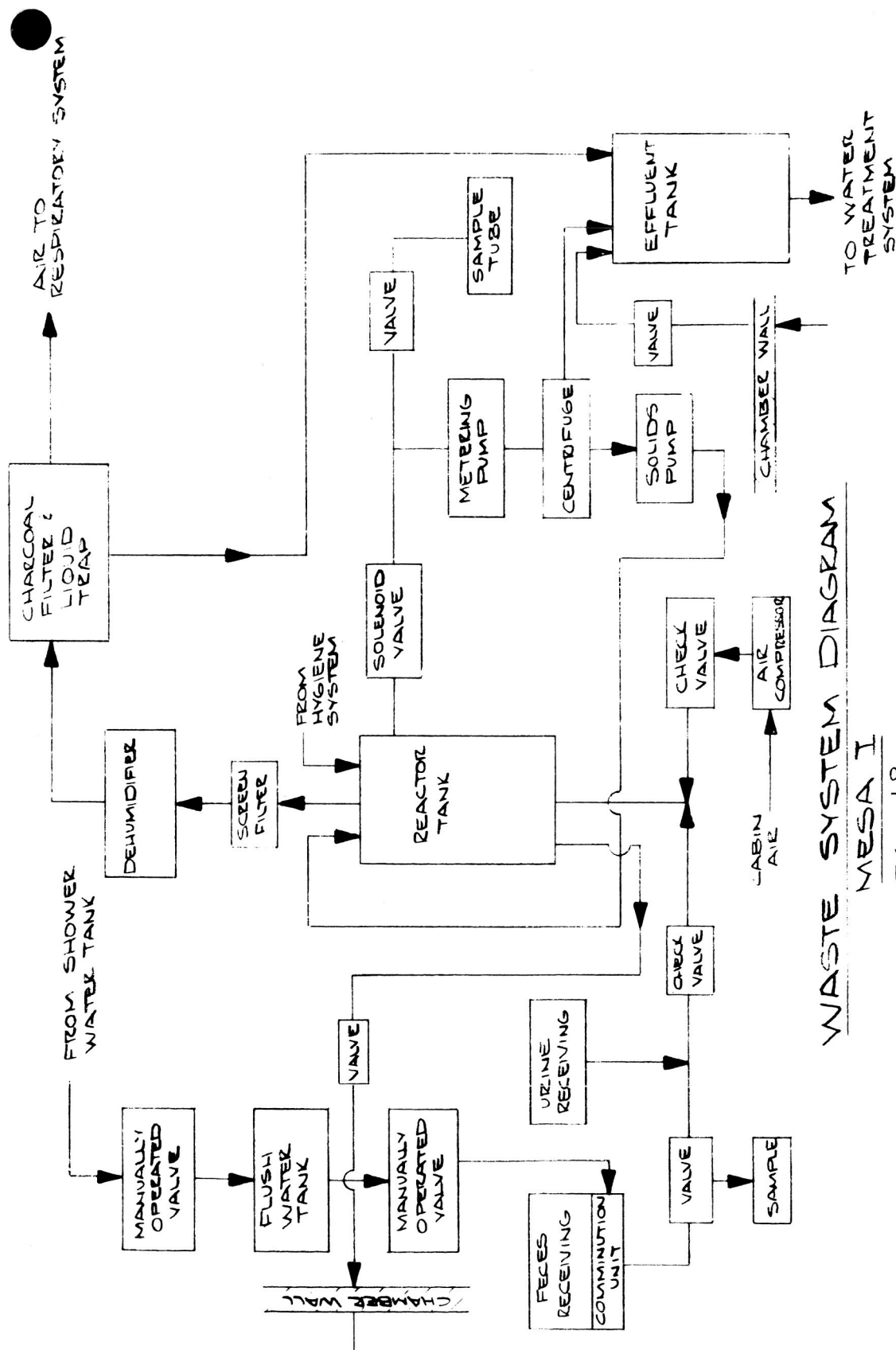
All components of the waste system were operated in the laboratory prior to installation in the chamber. The centrifuge, a commercial model, would not separate the waste culture on a self-cleaning basis as anticipated. The heavier material could not escape through the small orifices at the outer lower perimeter of the bowl, resulting in a substandard separation. Increasing the hole size allowed all of the liquid to escape resulting in no separation. The most successful modification to the centrifuge was achieved by utilizing centrifugal force acting on a rubber cylinder to alternately seal off or expose holes which were drilled in the lower outer perimeter of the bowl. Laboratory experiments showed that the bowl could be brought up to speed, filled, and the liquid successfully separated for a period of approximately two minutes. The speed was then reduced permitting the rubber cylinder to contract exposing the holes which allowed the cells to escape. By repeating the cycle approximately 8 liters of separated liquid could be produced within 60 minutes. It was noted, however, that the flush of cells from the bowl was not completely effective and that a residual accumulation would occur. It was decided to accept the prospect of a possible twice weekly cleaning of the centrifuge and include the unit in the waste system for the manned test.

#### SYSTEM TESTS

The final configuration for MESA I system tests is shown on Figure 18.

A two-day manned pre-test was conducted in July, 1963. During this test the system was operated without the centrifuge. The laboratory centrifuge was used to supply the supernatant with chamber penetrations provided for outside draining of the reactor and filling of the supernatant tank. The rest of the mechanical components of the system performed satisfactorily during this test.

The centrifuge performed satisfactorily during the first day of the attempted 30-day test, however, at the beginning of the second day the unit failed to provide acceptable quality supernatant. Further use of the unit required disassembly and



WASTE SYSTEM DIAGRAM

MESA I

FIG. 18

Fig. 18

cleaning approximately every 12 to 16 hours. Early during Day 4, it was decided to discontinue use of the centrifuge because of the frequency of cleaning and the general ill health of the crew.

Throughout the test excessive water was used for cleanup because of equipment malfunctions. This resulted in abnormal dilution of the culture, destroying its ability to biologically disintegrate the toilet paper. The ground up paper was mixed with the foam and remained on top of the liquid in the reactor tank. In addition the liquid level was allowed to go beyond the tank capacity on several occasions before it was detected. This action caused the screen in the exhaust line to become contaminated with paper particles. When the liquid level was lowered the paper adhered to the screen resulting eventually in completely plugging the exhaust outlet. Pressure then built up in the reactor and ruptured the sight glass gasket. This caused the final abort at day 4 1/2.

#### 6.1.3.2

#### MESA II

#### DEVELOPMENT

Results of the aborted test could be classified into two categories.

- A. Immediate configuration changes dictated by the test experience.
- B. A study, test, and evaluation program to determine the need for further configuration changes.

Items falling within the immediate change category were as follows:

- A. Provide for an emergency anaerobic condition whereby the reactor could be vented overboard.
- B. Increase the capacity of the dehumidifier unit in the reactor exhaust line to control the humidity to  $50\% \pm 5$ .
- C. Provided for a waste storage tank monitoring system consisting of the following components.
  - 1. A pressure indicating dial gage.
  - 2. An automatic pressure sensing switch actuating at approximately 4 psi was combined with an electrical system designed to shut off air compressor power, to illuminate a light at the command console, and to illuminate a light and energize a buzzer signal at the test conductor's station.

3. An automatic pressure relief valve set to relieve at approximately 6 psi was installed in an overboard vent line.
  4. A reactor tank quantity indicating system was used to provide a visual reading of quantity and to energize an electrical warning system which illuminated a light at the command console and a light and buzzer signal at the test conductor's station. The quantity measurement was achieved by weighing the reactor contents by suspending it on four springs. Changes in volume would deflect the springs with a relative displacement between the tank and the frame. A pointer and dial were used for visual measurement and a microswitch was actuated at high level to energize the electrical warning system.
- D. An electrical resistance probe was used as a sensor for low level warning in the supernatant tank instead of the previously used plastic float and microswitch combination. When the liquid level reaches approximately 1.8 liters the electrical warning system energized a light at the command console and a light and buzzer at the test conductor's station.
- E. It was questionable if the  $\text{NaO}_2$  was capable of removing the trace contaminant gases generated by the waste reactor. Therefore, the Hopcalite unit provided with heaters and blower was separated from the respiratory system and mounted in the waste system cabinet. The exhaust gases were ducted to the Hopcalite unit after passing through a silica-gel bed used to remove  $\text{NH}_3$ , thus preventing conversion to  $\text{NO}_2$  by the high temperature catalytic oxidizer.
- F. The peristaltic pump used to transfer liquid and air from the toilet to the reactor was replaced with a flexible liner-type pump because of the unpredictable tubing life and high probability of raw waste spillage resulting from tubing failure. Since the flexible liner pump was not capable of moving air, a duct was added connecting the toilet bowl to the Hopcalite blower duct. A butterfly valve placed in the duct and mechanically linked to the toilet slide valve allowed approximately 4 CFM of air flow when fully opened.
- G. The toilet was modified as follows:
1. A cylindrical extension providing a port for the Hopcalite air duct was added.
  2. A flush water spray ring was added to the top of the cylinder to wash the wall.



3. A baffle ring was added near the bottom of the cylinder to confine the slurry to the lower section during comminution.

Study, Test, and Evaluation programs were established to investigate the problem areas.

#### A. Centrifuge

A study was conducted to determine the possibility of arriving at an acceptable centrifuge for the waste system. These studies indicated an extensive preliminary design and development program would be required. It was considered that the schedule of this work would not fit into the MESA time table. Therefore, centrifuging of the slurry was to be performed outside the chamber on laboratory equipment.

- B. Redefine the requirements and configuration to ensure an aerobic reactor. Tests of the MESA I configuration showed that 10 CFM was required to ensure an "aerobic" condition. Since only 1.7 CFM was available, it was concluded that the reactor was most likely "anaerobic" during the MESA I 4 1/2 day test. The capability of supplying 10 CFM to the reactor was considered to be detrimental to a space weight reactor. Therefore, other means of driving the  $O_2$  into the liquid were investigated. A configuration which included driving the liquid over an air impinger plate was tested and the aerobic state was maintained with 1/4 CFM of air.

An undesirable by-product of this configuration was the generation of an abundance of foam. Confinement of the foam to the reactor tank was accomplished by the use of an electrically driven centrifugal wheel device acting as a liquid - air separator. The unit was installed in the top of the tank just below the air exhaust outlet. Evaluation of the configuration was made by conducting a continuous 30-hour laboratory test. During the test the reactor was fed 350 grams per day COD of total body waste and soapy water. The system was monitored by COD, dissolved oxygen, and exhaust gas analysis.

The results showed that the culture growth kinetics were normal and the exhaust gases revealed high  $NO_2$  and low  $NH_3$  concentrations and a culture pH of 6.0. The combination of low pH and high dissolved oxygen concentrations provided an adequate environment for nitrifying organisms, resulting in the evolution of large amounts of  $NO_2$ .

Further tests were conducted by operating three laboratory reactors at various air flow rate to evaluate the hypothesis that the formation of nitrite and the concentration of dissolved oxygen are related. The data obtained over the

62-hour period indicated that normal reactor performance could be obtained at a dissolved oxygen concentration of less than 1.0 mg/l; however, exact operating instructions for the actual reactor were unknown. It was decided that during the first two days of the 17-day integrated test determination would be made of proper air flow setting to ensure aerobic conditions and to maintain alkalinity (minimum NO<sub>2</sub> production). At this time, the reactor should be vented overboard to prevent possible chamber air contamination. After the proper air flow rate was established the reactor could be vented inboard.

At the conclusion of the development phase the following design refinements were made to the reactor system.

1. A resistance probe foam detector was added to the exhaust line from reactor. The detector electrically turned off power to circulating pumps, and energized a light and buzzer both inside the chamber and at the test conductor's station.
2. Reliability of liquid circulation was obtained by installing two centrifugal liquid circulating pumps.
3. A spare air mixing nozzle was provided as a replacement spare.
4. A dissolved oxygen meter was installed to provide continuous readout.

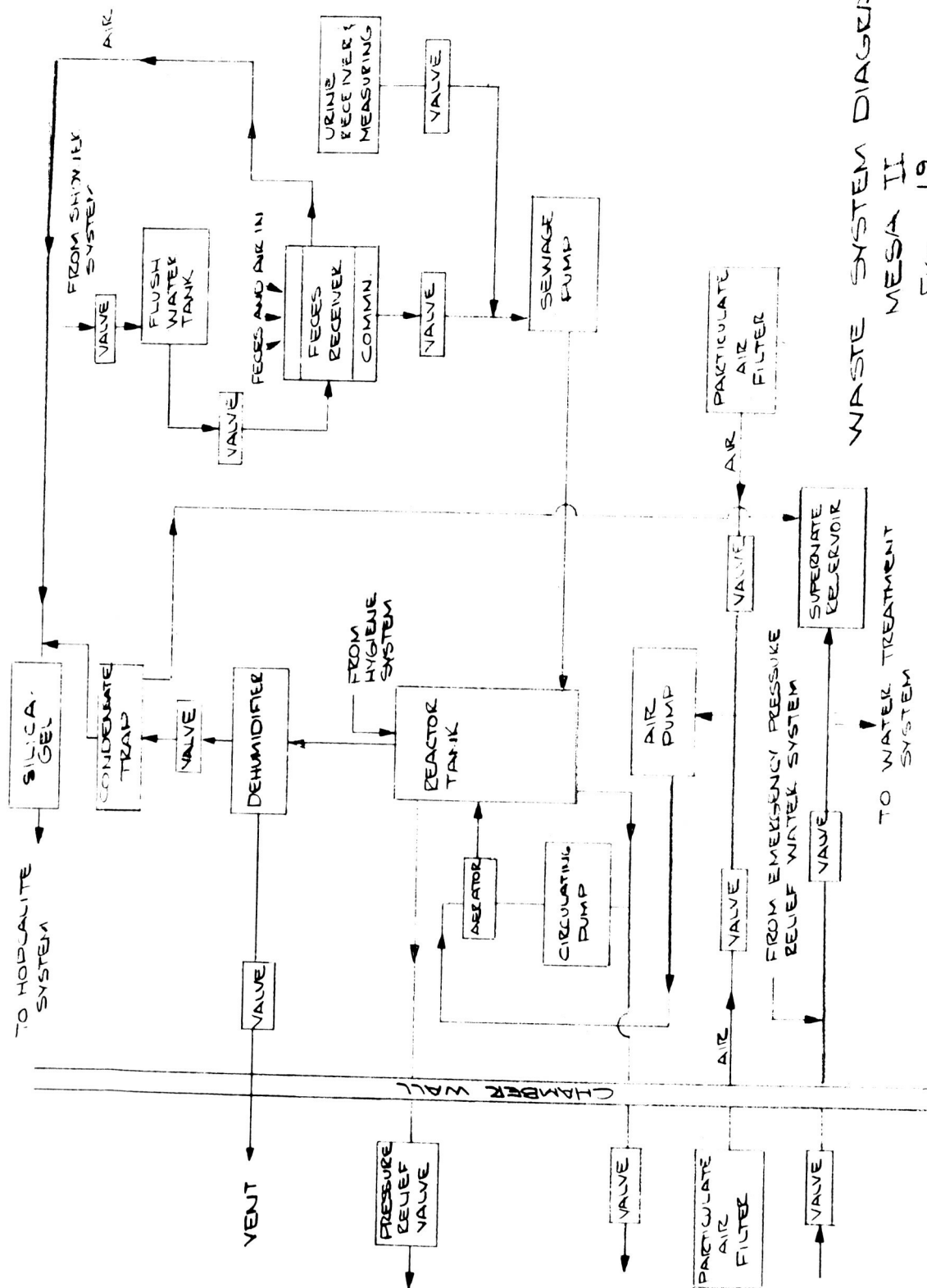
#### SYSTEM TESTS

The final configuration used in the MESA II Systems Integration and manned tests is shown in Figure 19.

During the 17-Day Test the system was vented overboard for the first two days. During this period the air and liquid flow were established which would ensure aerobic operation. Operation and results during the test are as follows:

- A. Airflow control erratic and required constant adjustment. Culture remained in aerobic state throughout test.
- B. Oxygen meter installed outside chamber malfunctioned because of electrical problem in the 40-foot cable.
- C. The reactor exhaust gas added 4.0 ppm NO<sub>2</sub> to the chamber atmosphere which was acceptable. (Note: reactor flow 0.1 CFM versus 600 CFM for cabin.)
- D. By running the reactor at NO<sub>2</sub> level of 200 to 300 mg/l instead of the 0 to 40 ml/l there would be a much greater buffer zone for sudden drops in the DO before anaerobic conditions occur.





- E. The increase in airflow would help to eliminate plugging of the mixing nozzle.

The operation of the waste system during the 30-day manned test was considered satisfactory. The following detail results were noted:

- A. The technique of liquid circulation and air mixing provides a satisfactory configuration for maintaining the reactor in an aerobic state. Difficulty was experienced with liquid circulation due to changes in cell concentration of the culture and with air control due to irregular pressure variations of the compressor. Frequent monitoring and adjustment were required of both functions throughout the run.
- B. It was found that between .2 and .5 mg/l of oxygen provided for the best waste degradation and lowest NO<sub>2</sub> formation.
- C. The culture feed for the run was a total of 7800 grams of COD of which 4300 grams were oxidized within the culture for a 55% efficiency. This efficiency would have been higher had the culture operated longer at steady state conditions. The culture did not approach steady state cell concentration of 33 grams/liter until midway during the test.
- D. Indications of possible anaerobic reactor conditions occurred three times during the run; accordingly, the reactor was vented overboard. On two occasions the vent time total was 11.5 hours and the third time the overboard vent was held for a 24-hour period to allow collection of humidity underflow water.
- E. Silica gel was found to be a very good absorber of NO<sub>2</sub> gases from the reactor exhaust. The column containing 995 grams was changed six times during the test for an average weight per man of 1194 grams.
- F. Measurement of pH was found to be a good parameter for determining presence of nitrites in the culture. Desirable operation occurs between a range of 7 to 8 pH.
- G. Examination of the culture showed that the toilet paper was not degraded as anticipated.
- H. The waste collection, transport, and flatus control systems performed satisfactorily. However, rinsing of urine cups with water after each use was found to be inadequate to control odor. During the test the cups and measuring container were passed out of the chamber for thorough cleaning in the lab every three days.

- I. Life of the DO sensor exceeded expectations and was changed once during the run.
- J. Aside from the anticipated silica gel column, air mixing nozzle and DO probe changes, the maintenance for the system consisted of the following:
  - 1. A seal on the liquid waste circulating pump was changed because a small leak developed.
  - 2. A leak developed in the pump used to transfer flush water to the toilet bowl. Upon disassembly it was found that a gasket had been improperly installed. The pump was reassembled and performed satisfactorily for the remainder of the run.
  - 3. During a conversion from overboard to inboard venting the air compressor inlet valve was left closed. This caused the compressor to overload the electrical motor which in turn tripped the circuit breaker. The valve was opened and the electrical circuit again energized. No further trouble developed.
  - 4. Near the end of the run the liquid pump appeared to be doing an inadequate job of waste circulation. The size of the pump pulley was changed from 3.75 to 2.50 inches in diameter. This change increased the pump velocity by 50% and restored adequate liquid circulation.

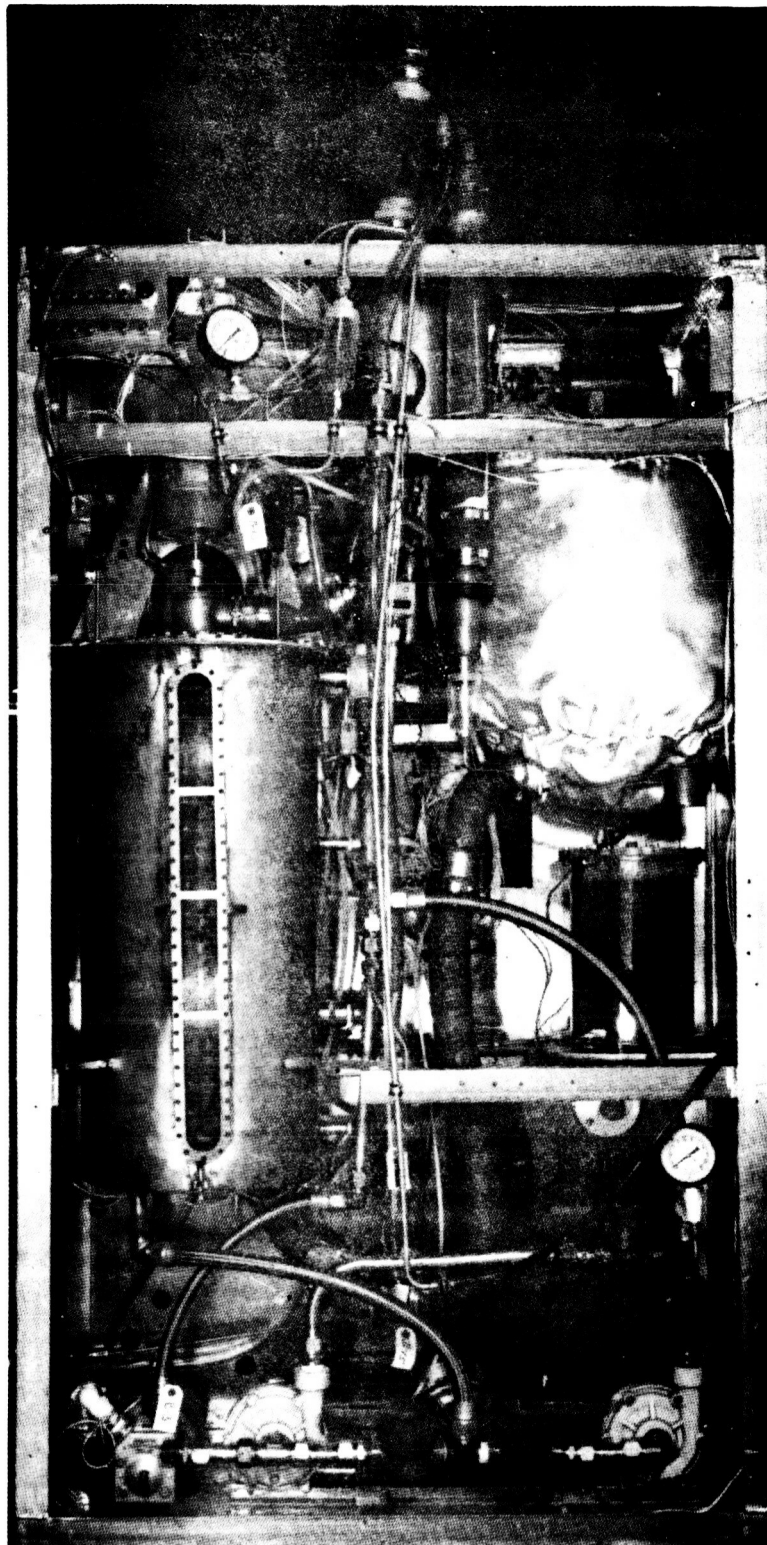
#### 6.1.3.3

#### RECOMMENDATIONS

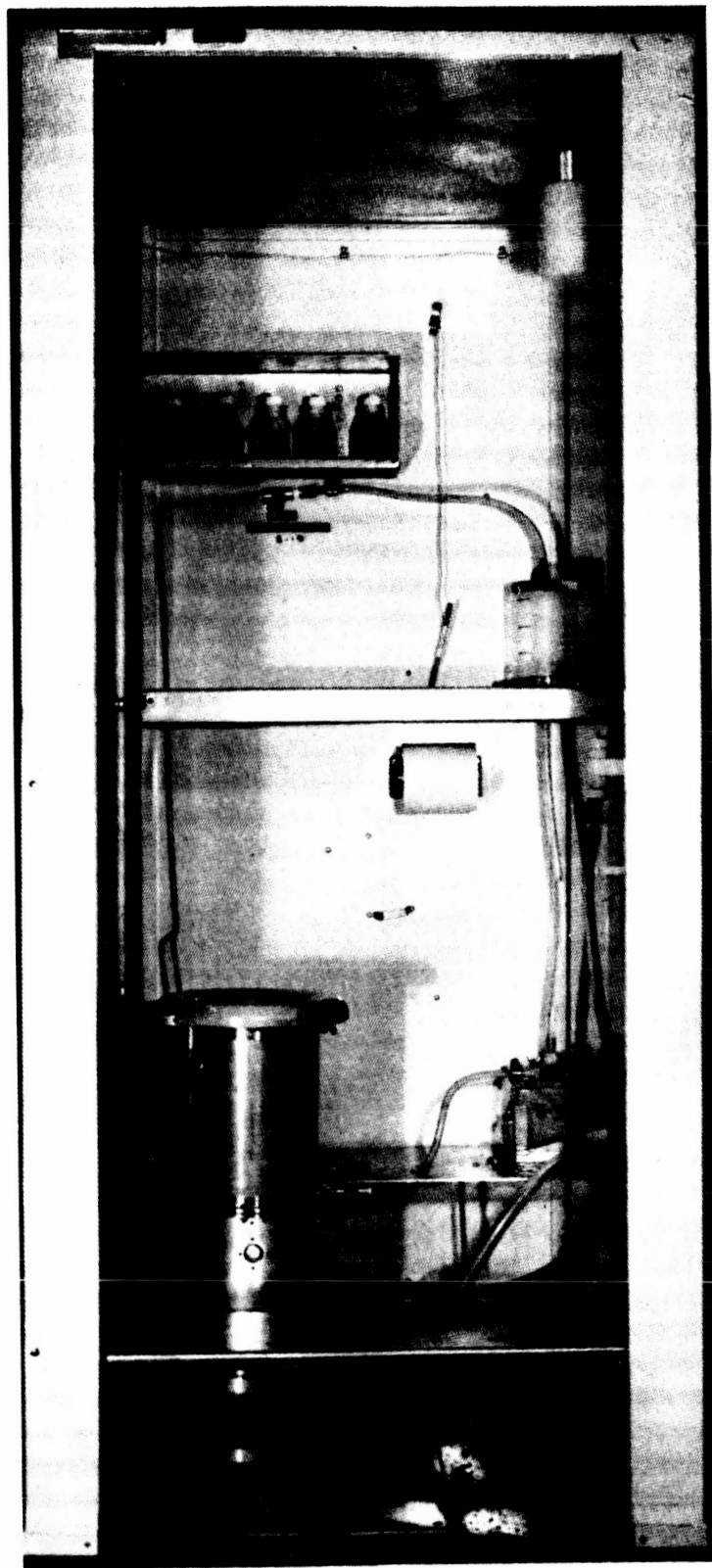
Future designs of the aerobic activated sludge waste systems should consider the following:

- A. Develop and test an instrumentation system capable of indicating positively the condition of the culture. The system should be capable of continuous monitoring with a warning signal to indicate an unacceptable culture state.
- B. In order to allow for changes in cell concentrations in the culture, the liquid circulating pump should be capable of providing controlled variable quantity output rates.
- C. An accumulator and/or a pressure-regulator should be provided for the air system to better stabilize the air flows and pressures.
- D. An investigation to determine the chemical analysis of a toilet paper that could be degraded in the waste reactor is required.
- E. Investigate the use of a chemically and toxicologically acceptable disinfectant for urinal cup odor control.

- F. Some of the problems related to the water system can be directly related to the improper laboratory centrifuging of the slurry. Since the water system is directly dependent upon waste system in this concept the quality of the effluent is very important. A major area of future work effort must be a definition of the effluent quality and the development of a centrifuge which can ensure the required quality.



**Photo 3:** WASTE TREATMENT SYSTEM COMPONENTS AND HOPCALITE UNIT — MESA II



**Photo 4:** TOILET ENCLOSURE SHOWING TOILET AND URINAL CUPS — MESA II

6.1.4

WATER SYSTEM

6.1.4.1

MESA I

DEVELOPMENT

The basic requirement was to provide a closed cycle water treatment system. To meet this requirement the water treatment system received all cabin refuse water and regenerated it into potable water. Refuse water included the waste system effluent (feces, urine, rinse water and hygiene water) and the humidity underflow.

The system utilized the following detail requirements for providing 5 men with water in the closed chamber.

A. Total production rate was dependent upon the following water usage requirements:

1. Drinking and food water      13.7 L/day
2. Personal hygiene water      11.3
3.  $\text{NaO}_2$  absorption      1.82 L/day

B. Regenerate refuse water at the following rates:

1. Waste system effluent      25 L/day
2. Humidity underflow water      5 L/day

C. The regenerated water had to meet the following arbitrary acceptance standards:

1. Less than 25,000 organisms/ML
2. Less than 2 caliform/100 ML
3. COD of less than 25.

The MESA water system design was based on the general concepts that effluent from the waste reactor was to be vaporized to remove nonvolatile materials, the volatile organic materials in the vapor were to be removed by an ion-exchange filter and the non-ionizing materials were to be removed by filtration.

The water from the humidity underflow was to be mixed with the condensed vapor to be de-ionized and filtered.

In order to accomplish this a water system was designed that consisted of the following components:

- A. A variable rate inlet pump.
- B. A liquid-liquid pre-heat heat exchanger (low temp).
- C. A wick type evaporator-condenser heat exchanger.
- D. A vapor pump.
- E. A vapor-vapor heat exchanger (high temp.).
- F. A catalytic oxidizer using alumina for the catalyst (1100°F).
- G. An air-liquid separator.
- H. An outlet pump.
- I. A "Barnstead Mixed Bed Ion Exchange cartridge.
- J. A charcoal filter.
- K. Electric heaters.
- L. Three conductivity meters.
- M. Storage tank.

Following early subsystem tests of the water system the vapor pump was removed. A suitable pump was not commercially available and a pump could not be developed within the time period that would perform satisfactorily. Excessive heat loss in the pump resulted in condensation of the vapor preventing any pump action. Because the vapor pump was removed from the system the electric power required for evaporation was increased, a glycol cooled condenser was added and an air compressor was provided for the oxidation air supply. Laboratory tests were conducted with the catalytic oxidizer and it was determined that by using a platinum-coated alumina catalyst the oxidation temperature could be reduced from the original range of 1100°F to 750°F.

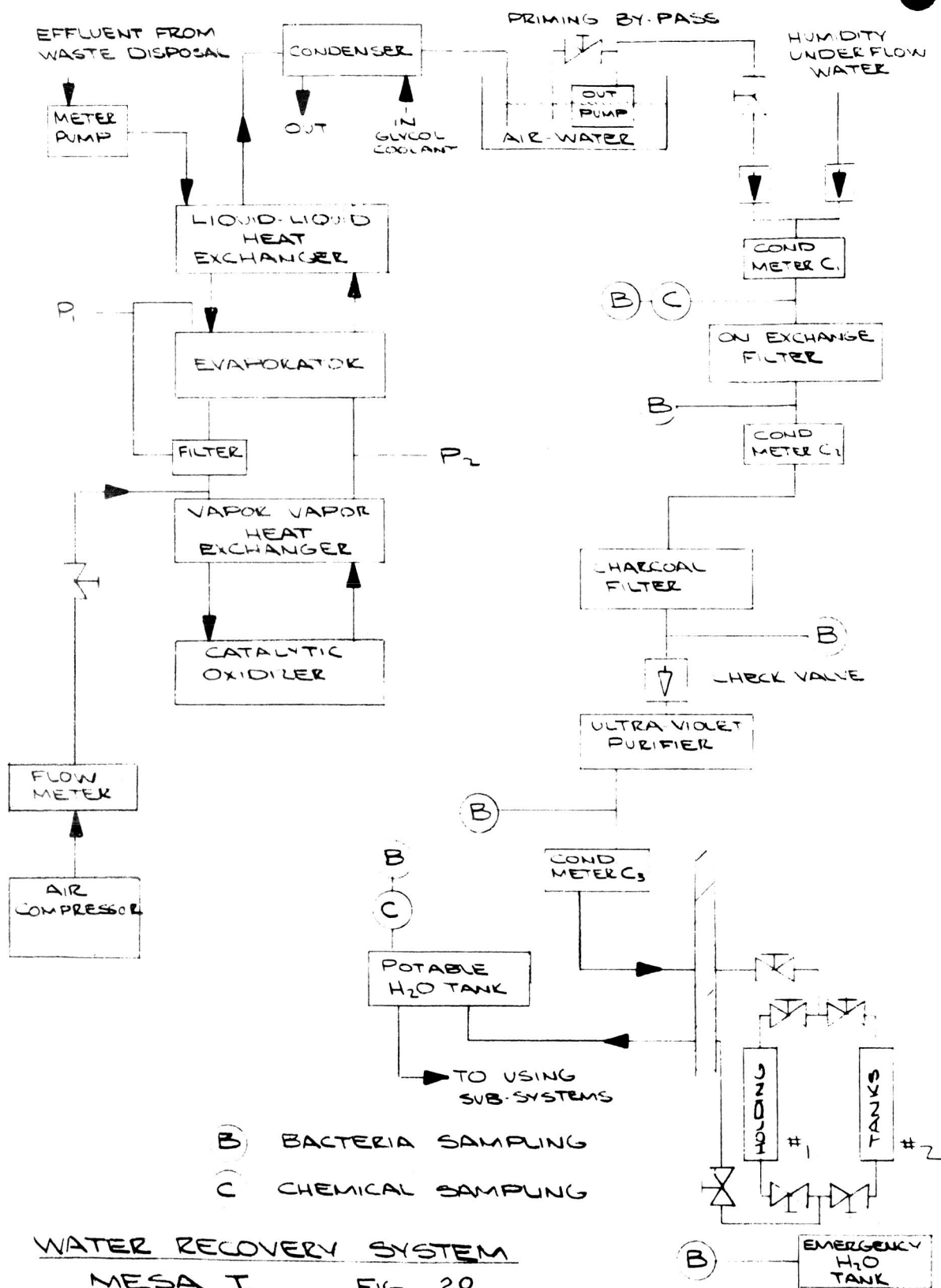
The wicking was removed from the evaporator-condenser as being unsuitable for use at 1 g conditions, because of lack of wicking ability, and as the wicks would clog with effluent, further reducing heat transfer. A filter was added to prevent effluent from reaching the high temperature heat exchanger. An ultra violet light was added for final sterilization of the water and the system was installed for the two-day preliminary run.

#### SYSTEM TEST

The final configuration is as shown by block diagram No. 20

During the two day pre-test to MESA I, water with an acceptable COD level was produced with the system using the platinum-coated alumina as the oxidizer catalyst. The bacteria content was high.





During the run it became apparent that the inlet and outlet pumps could not be synchronized, so the outlet meter pump was replaced with a submersible pump controlled by the liquid level in the sump. The level control was a styrafoam float-microswitch arrangement.

During the 30-day attempt (4 1/2 days) the preheat heat exchanger became clogged with effluent, was removed for cleaning, and bypassed. The slight reduction in efficiency was traded for simplicity. The variable rate inlet pump required periodic inspection of the evaporator level with a corresponding adjustment of the pumping rate. Failure to monitor the evaporator level frequently resulted in flooding the system with effluent, necessitating complete disassembly and cleaning of the system and replacement of the oxidizer catalyst.

After the flooding of the catalytic oxidizer the COD of the final water increased to an unacceptable level. The temperature of the catalytic oxidizer was increased to 1100°F in an attempt to lower the COD level. Since the catalyst was contaminated this did not produce an acceptable product.

During both the 2-day and the 4 1/2-day runs the system produced acceptable water chemically, but not bacterially, when the system was operated properly. The bacteria in the final water was due to the growths of contaminating organisms in the ion-exchange and the charcoal beds downstream of the catalytic oxidizer. Repetitive sampling of the water downstream of the catalytic oxidizers indicated that sterility was achieved at this stage.

6.1.4.2

MESA II

#### DEVELOPMENT

At the conclusion of the MESA I tests the requirement for the treatment of the humidity underflow water was changed. NASA requested that a separate purification system, based on filtration, be developed to determine if it was practicable to reclaim humidity underflow water alone.

In addition the detail requirements for the rate of water production were changed to the following:

A. Total production rate dependent upon the following usage requirements.

1. Drinking water and food - 12.2 L/day
2. Personal hygiene water - 10.0 L/day
3. NaO<sub>2</sub> absorption - 1.82 L/day

B. Regenerate refuse water at the following rates:

1. Waste system effluent - 21.4 l/day
2. Humidity underflow - 2.6 l/day

At the conclusion of the 4 1/2-day run the variable rate inlet pump was replaced with a large constant rate pump controlled by the evaporator level through a conductance probe.

At this time the water system was laboratory tested in order to obtain an indication of the confidence level for the components. During the course of this testing the conductance probe in the evaporator level control became contaminated and malfunctioned. The conductance probe was replaced with a photo-cell and float installed in the sight glass. If the sensitivity of the light was not properly adjusted the inlet pump would not turn on and the evaporator would go dry. This would cause the evaporator temperature to rise to excessively high levels. On one occasion the heaters, welded to the bottom of the evaporator, broke loose due to the high temperatures. In order to prevent the overheating of the evaporator an automatic overheat cutout was installed in the central circuit for the system.

During the testing the vapor heat exchanger and the filter became clogged and required cleaning. It became apparent that the filter was not stopping the foam from reaching the heat exchanger. In an attempt to reduce the foaming during the evaporation process and to increase the process rate up to the revised requirement of 24 liters per day, a new evaporator was built with a much larger liquid-vapor surface area. (The original evaporator modified for electrical heating could only sustain a 18.55 liters per day rate.) The tendency to foam was somewhat less but the foaming was still a serious problem so several methods of defoaming, including hot wire, cooled wall chambers and helical tubing, were tried without success. A motor driven centrifugal separator was developed and successfully tested and used in the final configuration.

The testing showed that there was  $\text{NH}_3$  in the air-water separator downstream of the condenser. The level control of the outlet pump was converted from a styrafoam float and micro-switch to an electrical probe and relay system because the  $\text{NH}_3$  attacked both the float and the microswitch. To keep the  $\text{NH}_3$  from entering the chamber the top of the air water separator was sealed. It was originally planned to vent the gases into the chamber through the hopcalite unit. In order to prevent the  $\text{NH}_3$  from converting to  $\text{NO}_2$  in the hopcalite unit, the gasses were vented overboard and the air compressor was replaced with oxygen bottles. (3 cc/min flow.)

In accord with the new requirement for a separate humidity underflow purification system, studies were conducted to determine a method of reducing the bacterial contamination and the COD of the the underflow water. The final system consisted of a "DYNION"

silver charcoal filter, ion exchange filter and a charcoal filter. Laboratory testing of this configuration proved the capability to provide acceptable water.

At the conclusion of the individual development programs the water system was tested in the laboratory to assure proper operation of the system components. During the 60-hour test the system operation was satisfactory. One possible problem developed in that the effluent caused a build-up of solids in the evaporator. It was determined that during system testing the evaporator would require flushing.

#### SYSTEM TEST

The final configuration for system testing is shown on Figures 21 & 22.

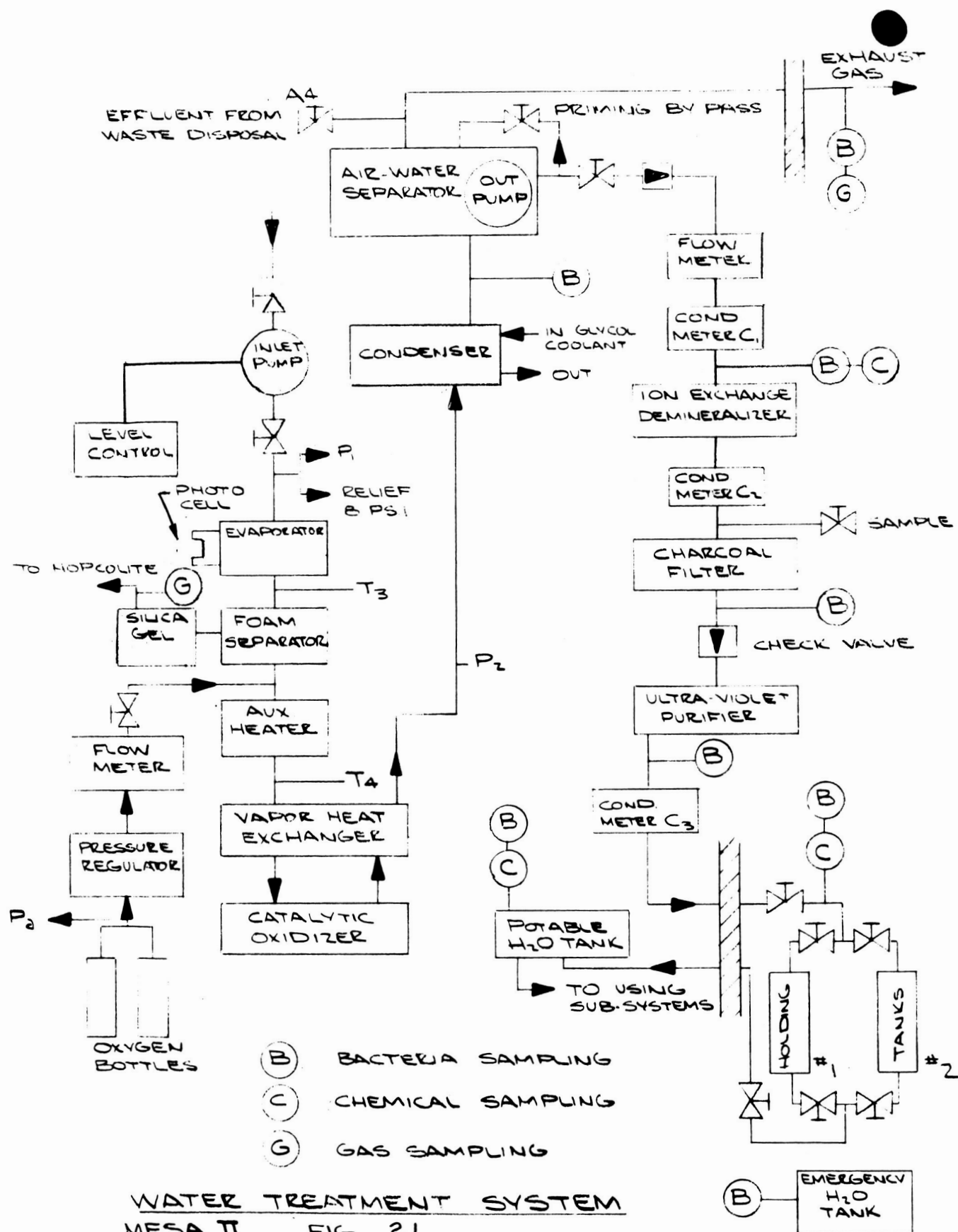
During the initial part of the 17-day integration test there were several instances of evaporator overheat due to improper adjustment of the intensity of the photocell light in the evaporator level controller. This problem was corrected by the proper adjusting of the intensity of the light.

There were several instances when the evaporator overheated due to plugging of the line between the inlet pump and the evaporator. This plugging was caused by foreign matter in the effluent from the waste system sealing the small inlet.

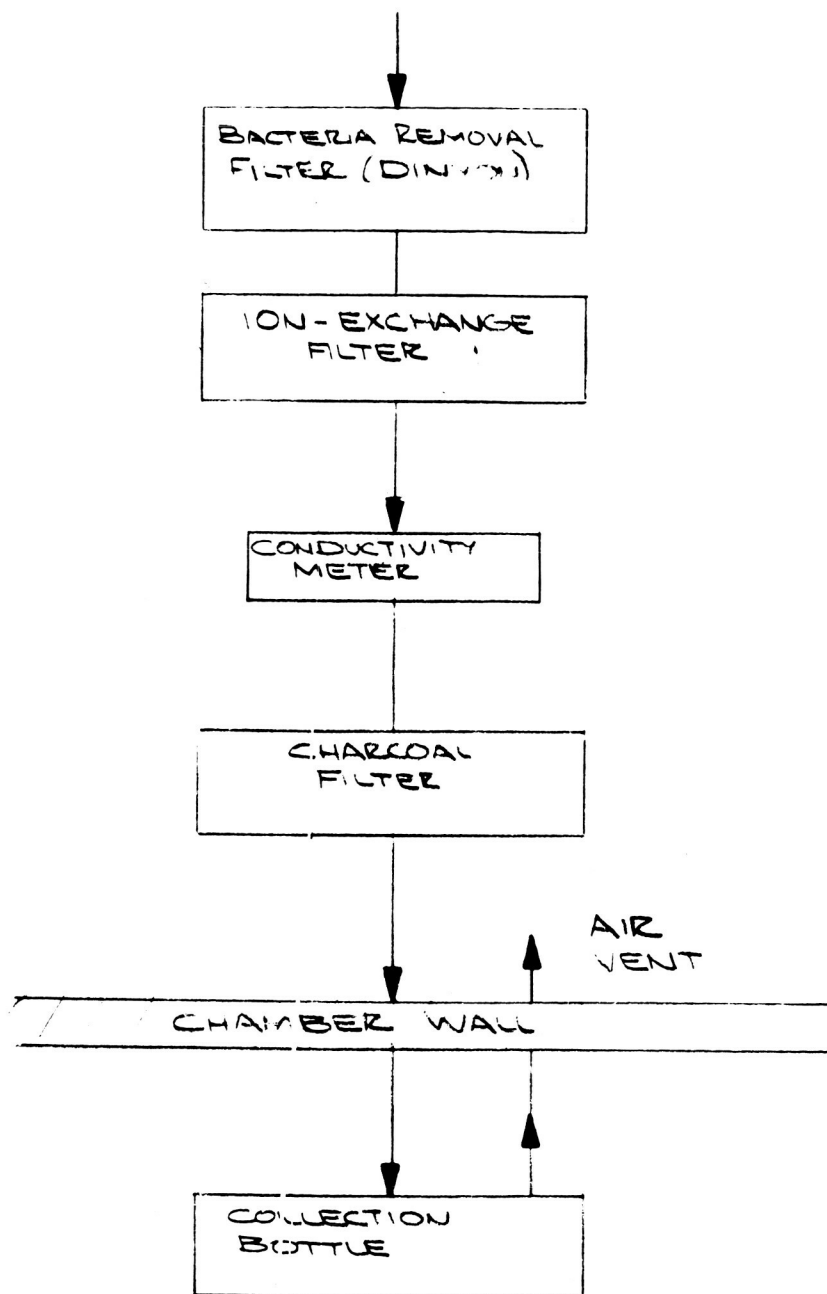
During the test, replacement rates were determined for the "water treatment" system and the "humidity underflow" system charcoal and ion-exchange beds. The humidity-underflow charcoal replacement rate could not be firmly established. The cartridges used had high initial COD's which did not allow for proper evaluation in the time available. It was determined that for the 30-day run the cartridges would be pre-flushed with distilled water and the COD's monitored to determine the time of change.

Based on the results of all prior tests the expected normal maintenance for the "water systems" consisted of the following:

- A. Replace ion exchange filter cartridge every day.
- B. Replace charcoal every 10 days.
- C. Replace oxidizer heater if heater malfunctions and the catalyst if the water has a high COD reading.
- D. Install fresh ammonia absorbers (silica gel) in the line from the water system to the hopcalite unit when the silica gel color changes from blue to pink to record blue front which has advanced the length of the ammonia absorber.
- E. Drain the evaporator every day.
- F. Replace pump tubing where failure of the part occurs.



CONDENSATE FROM TEMPERATURE  
& HUMIDITY CONTROL SYSTEM



HUMIDITY UNDERFLOW FILTRATION SYSTEM  
MESA II

FIG. 22

During the course of the thirty-day run six ion-exchange cartridges were used in the water system. This was five times better than the predicted usage rate. The cartridges were changed as indicated by the conductivity meter. The six cartridges weighed 21.2 pounds (total) which gave a usage (resupply) weight of 0.142 lbs/man/day.

Water system charcoal filters were changed three times. This was the same as the predicted usage rate. The charcoal weighed 1.77 pounds (total) which gave a usage (resupply) weight of 0.013 lb/man/day. The charcoal was changed when the final water COD was approaching 25.

The oxidizer heater operated for the thirty days without failure and the initial change of catalyst was still performing satisfactorily at the end of thirty days. The catalyst, platinum-coated alumina, weighed 0.10 pound. The ammonia absorber in the line from the water system to the hopcalite unit was never changed.

The evaporator was drained and flushed once a day. During the process one liter of liquid and the contained salts were lost. This reduced the efficiency of the system so that when water was being produced at the rate of 24 liters/day the recovery rate was 94%. In order to drain the evaporator the water system was shut down for an average of 45 minutes.

The inlet pump tubing was replaced on day 5, 11, 15, 25 and 26.

In addition to the normal maintenance there were several malfunctions that caused the water system to be shut down.

The defoamer failed on four occasions. Three times on the 7th, 15th and 24th days, due to seal failure which allowed the lubricant in the bearings to dry out causing failure. The fourth, on the 25th day, was due to poor assembly by the shop that overhauled the defoamer. The existing defoamer had an average life of approximately eight days and used inexpensive bearings and available seal components. The graphite-ceramic surfaces showed no appreciable wear. The ball bearing and graphite-ceramic seal used in the defoamer would be a satisfactory solution if high temperature bearings could be used and if the rubber boot in the seal could be replaced with a material that would be compatible with  $\text{NH}_3$  at 250°F.

On the 12th day the external refrigeration unit failed due to a leak which allowed the loss of freon from the unit. This caused the glycol system to become ineffective and the water system was shut down.

On the 13th day the auxillary heater was found to be plugged and on the 17th, 29th and 30th days the inlet to the evaporator plugged causing system shutdown. The plugging was due to solids in the effluent that was supplied from the waste treatment systems.

During the first several days of the run evaporate overheat would cause system shutdown for short periods of time. The system would stay off until effluent had been pumped into the evaporator, cooling it below the overheat cutout level. The problem was still due to the intensity of the light used with the photoelectrical cell being improperly adjusted. After establishing the proper intensity level no further problems were evident.

During the early stages of the test the flow from the outlet pump was erratic. Constant flow rates could not be maintained and continual priming of the outlet pump was required. The system plumbing was cleaned, the outlet pump replaced and the check valve was removed and calibrated without improving the system operation. It was determined that the conductance probes that turned the pump on and off were improperly set, allowing the pump to drain the air-moisture separator pump to such a low level that the pump would lose its prime. Raising the level of the probes solved the problem and the outlet pump performed in a satisfactory manner.

On the 19th day of the test the bacteria in the water exceeded the acceptable limit that had been established. The bacteria count remained high and on the 24th day the tubing between the U/V light and the holding tank outside the chamber was sterilized with alcohol in an attempt to reduce the high bacteria level. The water collected after the sterilization was acceptable; the alcohol flush drastically reducing the total bacteria count.

The water system was shut down for a total of 92 hours 19 minutes (12.82% of the time) due to malfunctions of the system components. It was shut down for a total of 16 hours 30 minutes (2.28% of the time) for normal planned maintenance. This was a total shut down time of 108 hours 49 minutes (15.1% of the 30-day run).

The expected normal maintenance for the "humidity underflow" filtration system was as follows:

- A. Replace pump tubing as required.
- B. Replace organic removal cartridge every 18 hours.
- C. Replace ion exchange cartridge every 18 hours.

During the course of the thirty day run the organic removal cartridges were used at the rate of one every 18 hours when the system produced good water from a chemical standpoint (COD 25). During the run there were periods of time when the system was used to provide special water samples and the cartridges were not changed. Based on the 1 per 18 hours usage rate, a total weight of 141.2 pounds would have been required to filter the underflow water. This is a usage (resupply) rate of 0.95 lbs/man/day.

The ion exchange cartridges were replaced three times during the course of the run. These weighed a total of 10.6 pounds which gave a usage (resupply) rate of 0.071 lbs/man/day.



The condensate pump tubing was changed on day 4, 10, 21 and 27.

The production requirement for the water treatment systems was 21.4 liters/day for the distillation system and 2.6 liters/day for the humidity underflow system for a total water production of 24 liters/day.

During the 30-day run the actual water production rate was 16.9 liters/day for the distillation water system and 7.9 liters/day for the humidity underflow system for a total production of 24.8 liters/day.

During the first 18 days of the test the crew used an average of 35.3 liters of water/day. This usage was in excess of the scheduled usage so water use was restricted. During the remainder of the test the crew used an average of 26 liters of water/day. This proved to be sufficient water to provide for the requirements of the crew and it is felt that less water could have been used.

The distillation water system produced less than the design requirement because of system down time due to malfunctions and because the system was operated at less than its rated capacity to balance the water production with the water usage rate.

The distillation Unit could have produced 25 liters of water per day in the "MESA" System, being limited by the effluent available from the waste system and system shut down. During laboratory tests, the distillation unit has produced acceptable water at the rate of 30 liters/day.

The Humidity Underflow production exceeded the design requirement, in part, due to the ion-exchange cartridges being changed three times during the run instead of one each 18 hours and due to the cabin relative humidity being kept at approximately 40% instead of 50%.

For the water chemical analysis and results see Figure 23  
For the Water Balance Tabulation see Figure 24.

TEST		17 DAY PRETEST		30 DAY MANNED	
RESULTS		RANGE	AVERAGE	RANGE	AVERAGE
mg/liter		mg/liter	mg/liter	mg/liter	mg/liter
WATER SYSTEM	Post Oxydizer				
	A C.O.D.	0-152	46.4	0-350	42.7
	B Ammonia	7.5-425	217	0-350	100.7
	C Nitrate	0-115	9.6	0-87	7.0
	D Nitrite	0.5-232	24.9	1-50	26.0
	Final Drinking Water				
	A C.O.D.	0-33	8.6	0-155	7.7
	B Ammonia	0-0	0	0-5	0.25
	C Nitrate	0-0	0	0-0	0
	D Nitrite	0-0	0	0-0	0
HUMIDITY UNDERFLOW	Before Filtration				
	A C.O.D.	52-304	101.8	80-1040	308.5
	B Ammonia	0-18	11.8	12-32	17.0
	C Nitrate	0-0.8	0.18	0-0	0
	D Nitrite	0.1-16	1.74	0-1.5	0.19
	Final Humidity				
	A C.O.D.	0-74	27.6	0-254	43.5
	B Ammonia	0-0	0	0-12	1.08
	C Nitrate	0-0	0	0-0	0
	D Nitrite	0-0	0	0-0	0

Water Chemistry: Samples from the humidity recovery and water recovery systems were tested every 8 hours for Ammonia, Chemical Oxygen demand, nitrate, and nitrite Concentrations. The methods employed were taken from the eleventh edition of Standard Methods for the Examination of Water and Waste Water. Results for nitrogen analyses were reported as mg/liter as N.

#### MESA II - WATER CHEMICAL ANALYSIS

Figure 23

WATER BALANCE

WATER "IN" = 1576.8 L

WATER "OUT" = 1576.0 L

	<u>WATER SYSTEM</u>	<u>HUMIDITY SYSTEM</u>	<u>COMBINED SYSTEMS</u>
TOTAL PRODUCTION	507.1 L	237.3 L	744.4 L
TOTAL ACCEPTED	234.6 L	88.6 L	323.2 L
TOTAL REJECTED	272.4 L	148.7 L	421.2 L

WATER REJECTION CAUSES

	<u>COD</u>	<u>COLIFORM</u>	<u>TOTAL BACTERIA</u>	<u>COMBINATION</u>	<u>NOT MEASURED</u>
WATER SYSTEM	46.0 L (ALCOHOL)		176.6 L	34.2 L	17.0 L
HUMIDITY SYSTEM	38.4 L	17.4 L	21.6 L	61.8 L	8.8 L

## WATER BALANCE SUMMARY

MESA II 30 Day Manned Test

Figure 24

#### 8.1.4.3 Recommendations

Based on the operation of the water system during the MESA Test the following recommendations are made that would improve the design of a system using effluent from an activated sludge waste system for the treatable liquid.

- A. The effluent tank must have cleaning provisions; stirring, scraping and possibly re-centrifuging the effluent.
- B. The inlet lines to the system should be increased in size. The lines to the evaporator should not be less than 3/8" I.D.
- C. The inlet pump (or valve if vacuum system is used) should be large enough to resist clogging, eg. a large 1/4 or 3/8 peristaltic pump turning very slowly. The inlet pump rate should be only slightly more than the maximum expected rate.
- D. The evaporator must have provisions for handling solids. If drain is used then stirring paddles wiping all surface would be required.
- E. A vacuum distillation system should be investigated as a possible means of reducing foam and of eliminating the heat loss in the vapor pump if one is used.
- F. A larger foam separator rotor (4" Dia.) would give a little safety factor for foam control. There were times that the 2" Dia. rotor did not quite keep the foam in control.
- G. The pre-heat and vapor heat exchangers should have larger passages to guarantee no clogging. Fins inside the preheat exchangers are probably not necessary, also provisions for disassembly and cleaning should be made.
- H. A vapor pump of the diaphragm or rootes type should work well and reduce the power requirements if used with the vacuum distillation. The previous failure of vapor pumps was almost certainly caused by excessive heat loss in the pump resulting in condensation of the vapor thus preventing any pumping action. Vacuum distillation with the proper pressures ( .5 psia) will allow the vapor pump to operate at room temperature thus eliminating the condensing problem.
- I. The outlet pump should be a positive displacement (self priming) type of pump.
- J. New controls may have to be worked out if vapor compression system is used.
- K. The present oxidizer catalyst bed is probably marginal and should be increased in area.

- L. When a new vapor heat exchanger is designed, it should wrap around the oxidizer to minimize total heat loss to cabin and make system more compact.
- M. The oxidizer temperature should be operated by a controller, probably a thermocouple type on case. The over-temp control should have its sensor on the heater itself to provide better safety against burnout.
- N. More investigation is needed to learn how to reduce Post ox COD and thereby reduce filter requirements. Oxidizer temperature and  $O_2$  rate should be optimized.
- O. Addition of bactericides should be further investigated since maintaining germ-free system apparently is not practical down-stream of the cat oxidizer.

In addition the following recommendations are made for establishing system design parameters.

- A. "Acceptable water" should be better defined. At present, none of the water standards provide a definition for a unnatural (closed-cycle) water treatment system end product. Also, the tests required to assure the quality of the product should be defined.
- B. The input liquid should be defined. In the case of effluent, the total solids, COD, N,  $H_2S$ ,  $NO_2$  and Cl should be determined.
- C. The process rate requirement should be better defined. A wide range of rates can occur, varying from less than  $1/2$ , the expected normal rate to almost twice the expected normal rate depending upon the water usage rate of the crewmen.

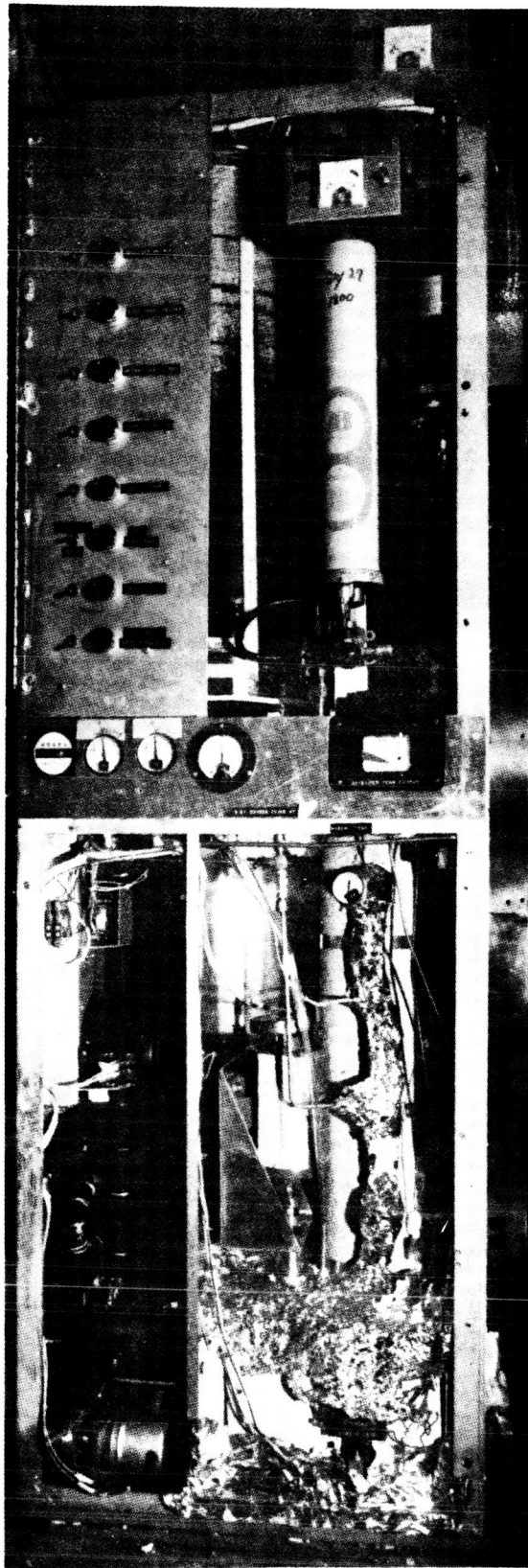


Photo 5: WATER TREATMENT SYSTEM — MESA II

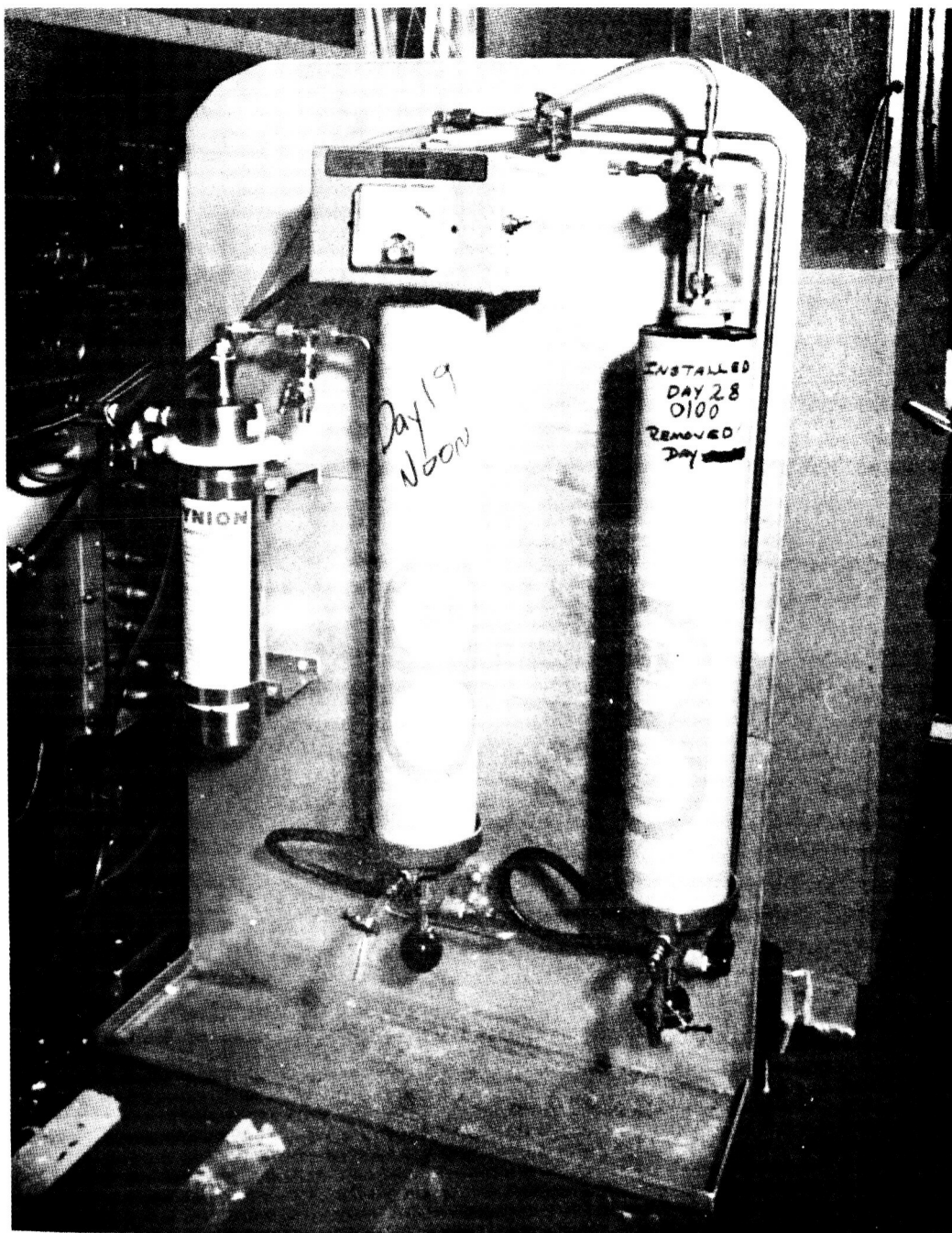
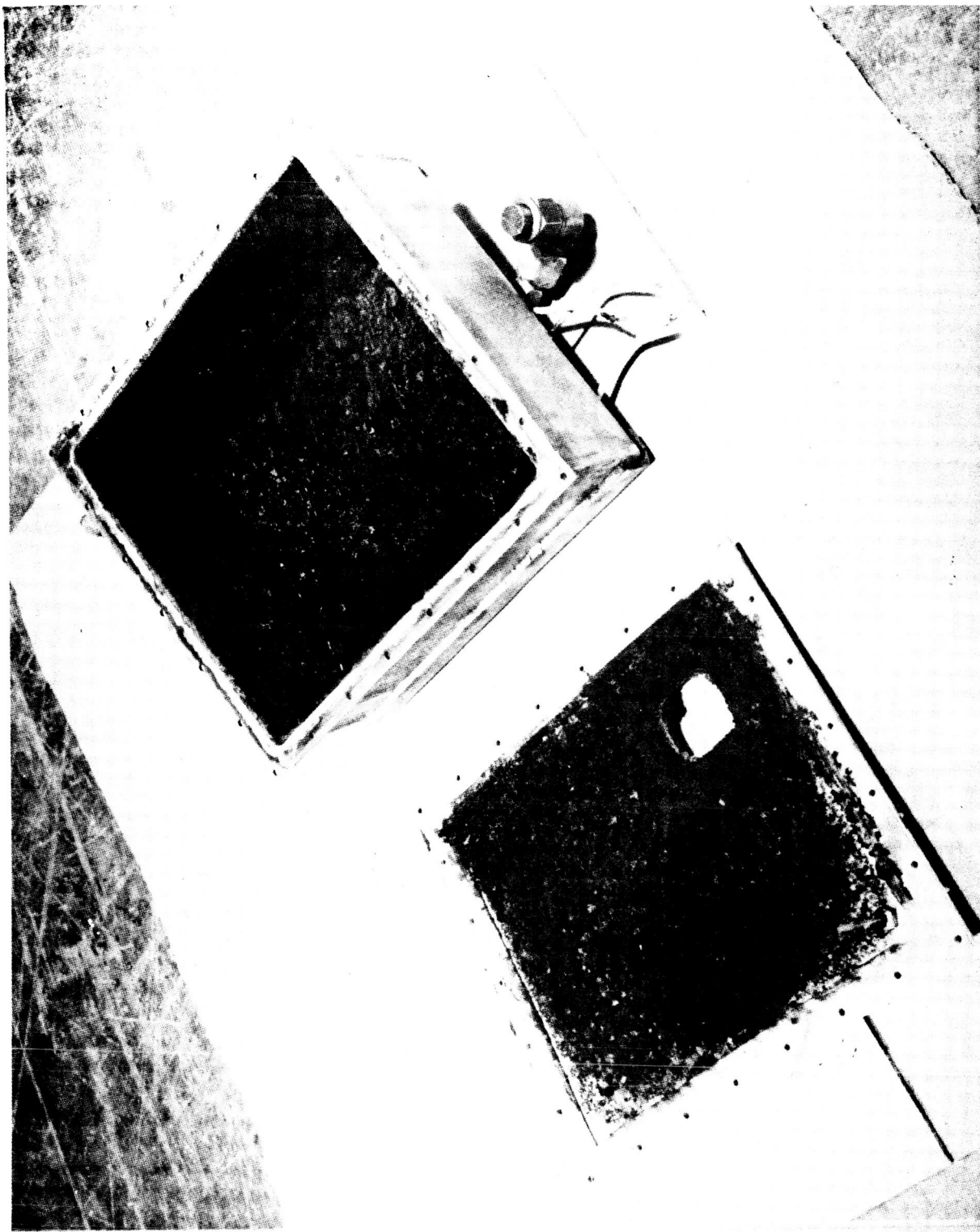


Photo 6: HUMIDITY UNDERFLOW SYSTEM — MESA II



**Photo 7:** WATER SYSTEM EVAPORATOR AT COMPLETION OF 30 DAY TEST — MESA II



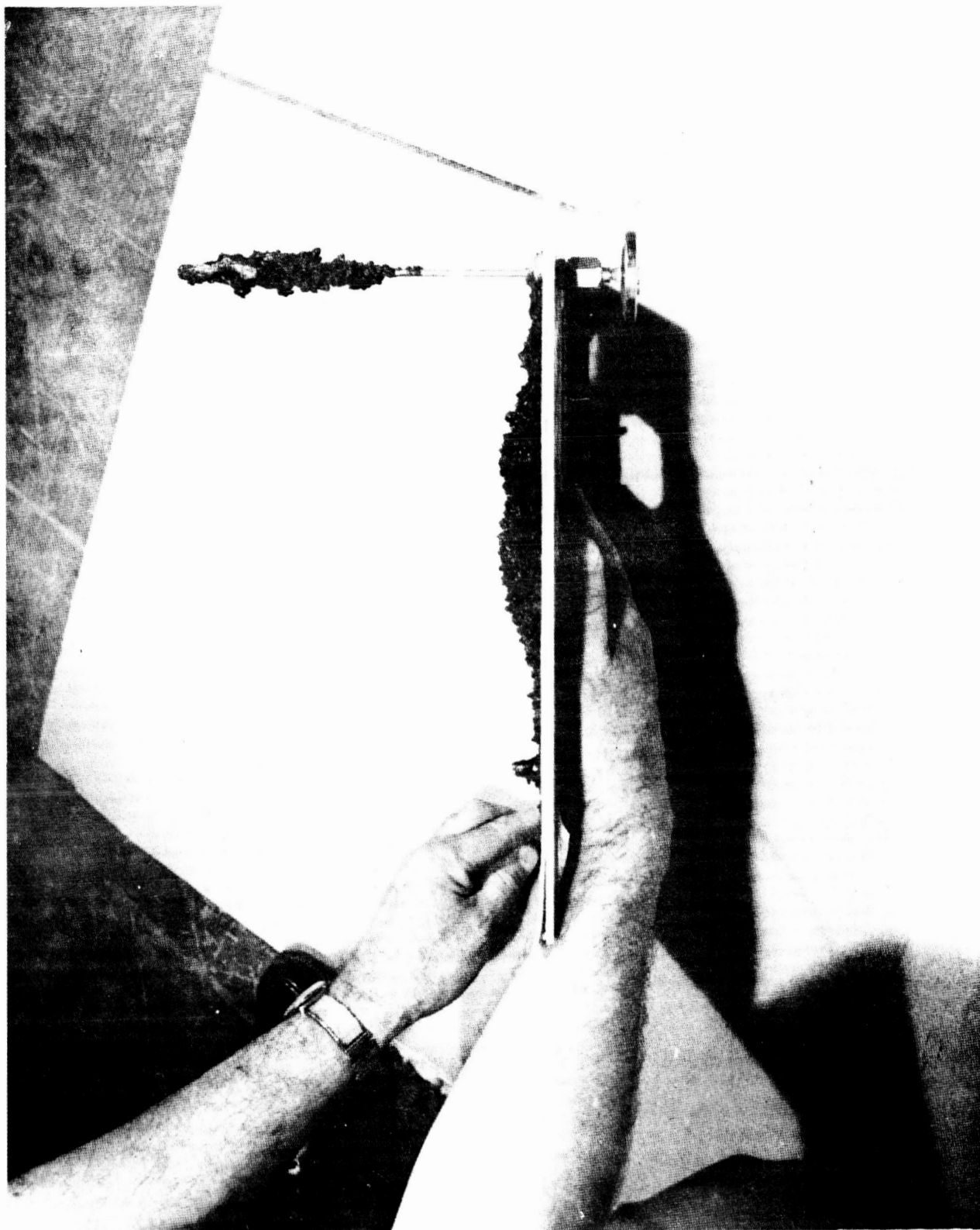


Photo 8: WATER SYSTEM EVAPORATOR COVER AT COMPLETION OF 30 DAY TEST — MESA II

6.1.5

RESPIRATORY SYSTEM

6.1.5.1

MESA I

DEVELOPMENT

The respiratory system shall produce the breathing atmosphere for five men during a 30-day period in a closed environment by maintaining the atmosphere oxygen concentration between the limits of 19.0% and 23.0% and the carbon dioxide concentration below 1.5%. The atmosphere shall be provided by the use of sodium superoxide for the generation of oxygen and subsequent absorption of carbon dioxide. Trace atmospheric contaminants, e.g., carbon monoxide, methane, hydrogen and organic aerosols, shall be maintained at safe equilibrium levels if existent.

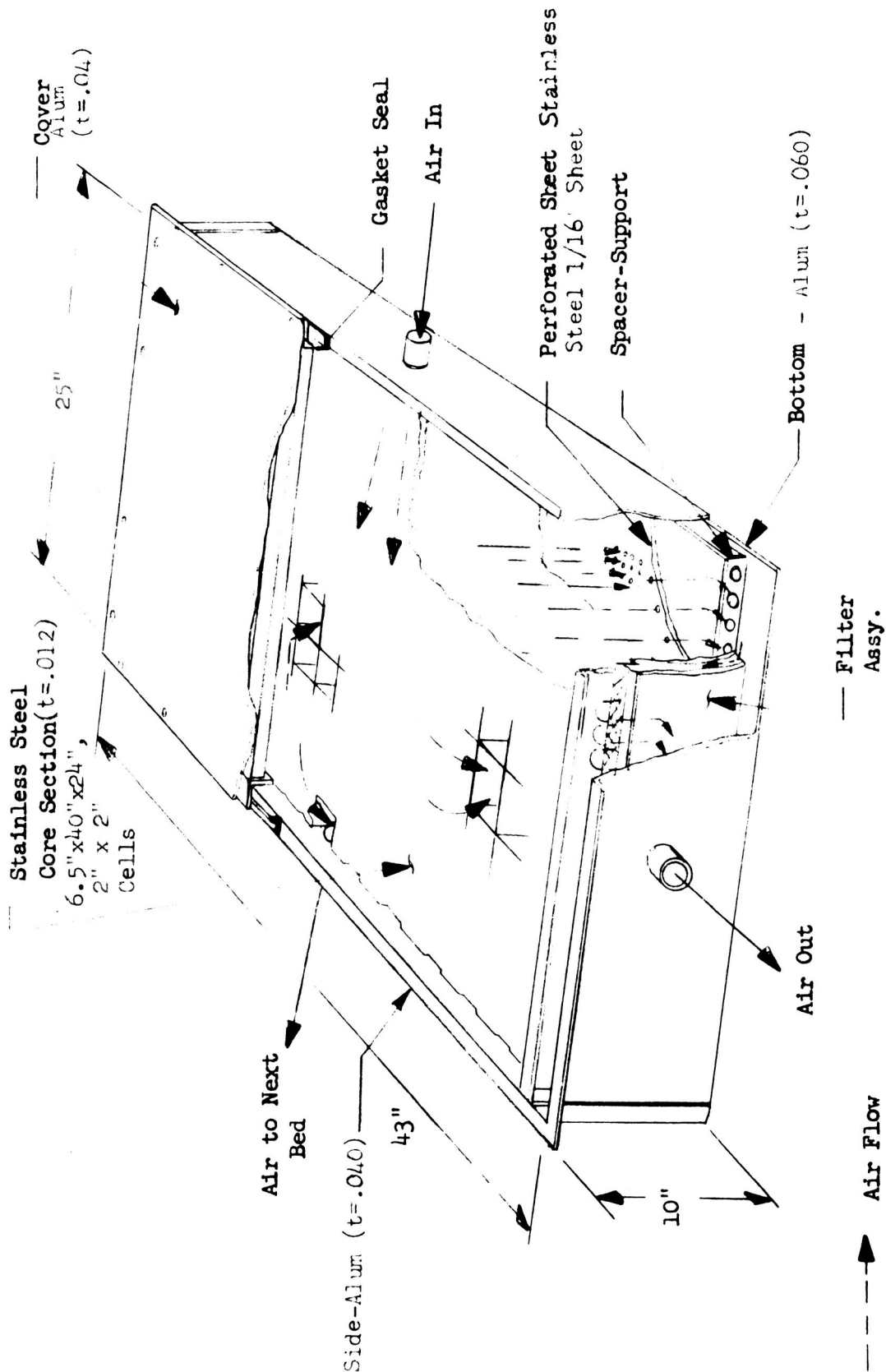
The respiratory system design concept for a 5-man integrated life support system was developed on the basis of earlier work and consisted primarily of six fixed beds of oxide connected in series with parallel, selective flow control of humidity regulated air through one or more of the beds. A catalytic unit to oxidize trace contaminants and an additional chemical carbon dioxide absorber were considered required adjuncts to the basic system.

Each bed, containing 150 pounds of sodium superoxide, was calculated to have a theoretical life of 5.8 days; six beds giving a 4.8 day margin in excess of theoretical requirements. A multiple blower unit consisting of three multistage blowers was specified to insure continuous air flow; one blower to be adequate for oxygen requirements. A central air flow control manifold was proposed for regulation of the six bed air outlets. The exit from the manifold was considered the optimum location for system air flow indication and, to indicate this flow, development and fabrication of a calibrated thermistor anemometer was specified.

The large, fixed bed concept was considered to have the following advantages over smaller (one day) canisters used in earlier work:

- A. The crew is not required to handle 900 pounds of superoxide by installing fresh canisters and disposing of used canisters.
- B. Better absorption rates of carbon dioxide could be achieved by reacting larger volumes of chemical with a low velocity airstream provided by beds of large cross-section.
- C. Six beds in series with parallel selective flow control would permit better regulation of oxygen generation relative to carbon dioxide absorption.
- D. Chamber volume could be better utilized with fixed beds.

Air humidity to the beds, considered a critical factor in the superoxide reaction from earlier work, was to be regulated by use



SUPEROXIDE BED - RESPIRATORY SYSTEM

Figure 25

of a dual bed, regenerable silica gel unit incorporating a servo bypass valve for mixing chamber air with dried air to give a desired humidity. Development and fabrication of a humidity set-point controller was specified to give the automatic regulation desired.

To remove trace contaminants and to concurrently supply heated air for silica gel regeneration, a combination air heater and catalytic oxidizer was conceived. The unit was to have a manual bypass to regulate the temperature of the air to the regenerating silica gel (220°F) and a heater controller to maintain the temperature of the catalyst at 600°F.

Previous work had indicated that carbon dioxide absorption rate lagged behind oxygen generation rate. The use of an independent carbon dioxide absorption system was specified to prevent excessive oxygen concentrations while maintaining required carbon dioxide levels. The system was conceived as a dual blower cabinet containing two honeycomb cores, holding 12 pounds of lithium hydroxide each, mounted in series. Lithium hydroxide was specified because of its high ratio of weight of CO<sub>2</sub> absorbed per unit weight of absorbent and its lack of efflorescence.

Crew regulation of the respiratory system was considered best accomplished by instruction from outside monitors since it was not feasible to install and maintain the available instruments for atmosphere analysis in the chamber. On the basis of the trends of chamber oxygen and carbon dioxide concentrations, it was assumed that system air flow rates and air humidity could be varied to maintain oxygen and carbon dioxide within specified limits.

Superoxide and the catalytic oxidizer were assumed to be effective bactericidal agents but it was thought that some bacteria would be trapped in the silica gel before reaching the oxide and be released to the chamber on regeneration of the gel. Therefore, bactericidal ultraviolet lamp units were specified for the exhaust ends of the silica gel canisters.

The use of alkali superoxides for the maintenance of breathing atmospheres in closed systems has been investigated intermittently by The Boeing Company since 1959. Relevant Boeing documents are:

- D2-9545      Chemical Air Recycling Systems
- D2-90217     Studies of Solid Chemical Oxygen Regenerating Systems
- D2-90254     Summary Report - Project Crest

Investigations completed prior to MESA I manned chamber tests were:

#### A. Bench Scale Respiratory Quotient Test

A laboratory test of sodium superoxide reaction with air containing given amounts of carbon dioxide and water vapor demonstrated that oxygen evolved rapidly during the initial reaction at a rate equivalent to a respiratory quotient ( $R.Q. = \frac{\text{Vol. of CO}_2}{\text{Vol. of O}_2}$ ) of 0.6. As the reaction continued, oxygen production decreased and CO<sub>2</sub> absorption increased resulting in a R.Q. approaching the nominal value for humans of 0.80. At the end of the test the average R.Q. exceeded 0.90. From this data it was concluded that sodium superoxide could provide adequate CO<sub>2</sub> absorption capability but that some lithium hydroxide would be required to control CO<sub>2</sub> levels during the initial stages of superoxide reaction.

#### B. MESA Respiratory Sub-System Prototype Tests

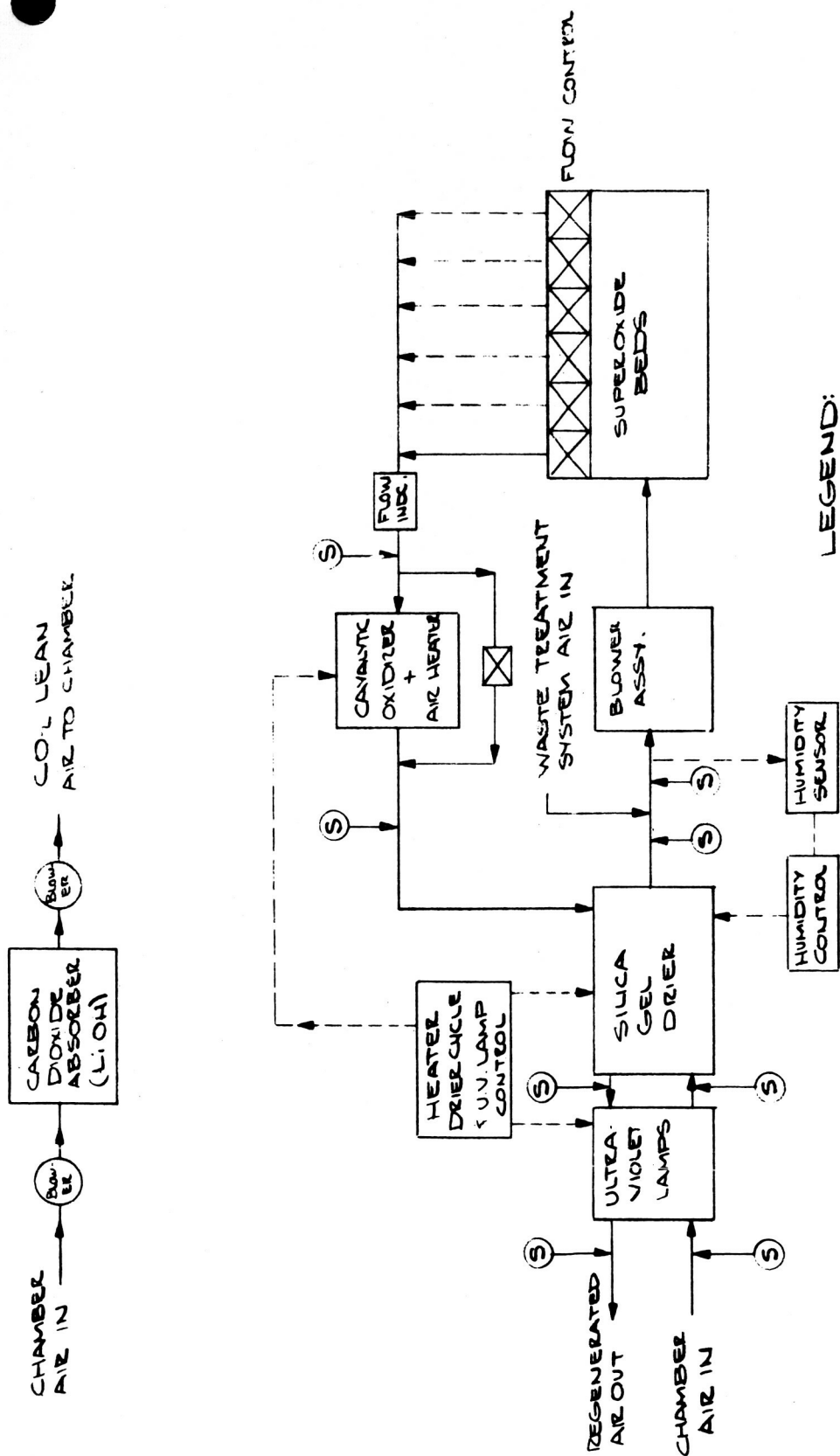
A complete respiratory sub-system prototype using a chemical bed containing 98 pounds of potassium superoxide was operated continuously for four days in a laboratory test. Difficulties were encountered with overheating of a particulate filter located upstream of the catalytic oxidizer ("Hopcalite") heating elements and with regulation of the oxidizer heaters. The phenolic fiberglass honeycomb used in the bed was found to react to some extent with superoxide resulting in discoloration and corrosion of the phenolic resin. The oxygen production and carbon dioxide absorption rates were similar to those attained in previous tests, confirming the need for additional CO<sub>2</sub> absorption capacity.

Following the test, the particulate filter was removed from the catalytic oxidizer and not used for the manned testing. The phenolic honeycomb bed cores were replaced with aluminum foil honeycomb cores. Stainless steel cores could not be obtained in time for MESA I.

#### SYSTEM TESTS

The system was assembled in the chamber for manned testing as shown by Figure 26. The silica gel drier, ultra-violet lamp assemblies, catalytic oxidizer, bed manifold and control instrumentation were installed in the command console. The oxide beds were mounted in the ceiling of the chamber on support rails.

The performance of the respiratory sub-system was tested as part of an integrated life support system test. Five men were supported for 48 hours in a closed chamber with one bed containing 58 pounds of sodium superoxide of approximately 92% purity. Oxygen concentration was maintained between 19.6 and 21.7% during the two-day period. The carbon dioxide concentration averaged 1.35%, reaching a maximum of 1.7%. The CO<sub>2</sub> level was reduced by



LEGEND:

- GAS FLOW
- - - ELECTRICAL
- (S) SAMPLING TAP (GAS OR BACTERIA)

MESA I RESPIRATORY SYSTEM  
FLOW DIAGRAM

FIG. 26

increasing air flow through the bed during latter stages of operation. Since oxygen and  $\text{CO}_2$  percentages were maintained at a fairly constant level during the first 44 hours of operation, it was assumed that the superoxide reaction was matching the R.Q. of the crew. Analysis of the bed material following the run indicated a yield of 70% of the theoretical amount of oxygen available. Bed output of oxygen during the last 4-5 hours of operation was not sufficient to maintain equilibrium. Total oxygen consumed by the crew was calculated as 18.8 pounds or 1.88 pounds/man-day.

During the test, system malfunctions occurred in cycling of the silica gel drier and in regulation of the catalytic oxidizer heating elements. The drier valve actuation servo-mechanism was subsequently reworked and the heating elements of the catalytic oxidizer were put on separate switches (4) to improve control.

Hydrogen was evolved by the action of sodium hydroxide (formed during the initial reaction of sodium superoxide with water vapor) with the aluminum honeycomb core and increased in concentration during the test period to a maximum of 2800 ppm. The catalytic oxidizer was not able to maintain an equilibrium level of  $\text{H}_2$  because of limitations of temperature and flow caused by superoxide bed and silica gel drier requirements. It was assumed that, with continued operation, the generation of  $\text{H}_2$  would reach a maximum rate and then decrease as the hydroxide was converted to carbonate and that the catalytic oxidizer would be capable of maintaining a safe (though high) equilibrium level eventually.

No illness or atmospheric odor was experienced by the crew except for a short period when the catalytic oxidizer became overheated resulting in the oxidizer insulation evolving fumes causing nausea and headache.

During the first 4 days of the planned 30 day test, the respiratory system malfunctioned as follows:

- A. Hydrogen was evolved by the superoxide beds and continued to increase in concentration, reaching a maximum of 1440 ppm at the end of 4 days. Since the catalytic oxidizer was integrated into the superoxide bed air flow system and its operational limits were dictated by bed and silica gel drier flow and temperature requirements, an adequate rate of  $\text{H}_2$  elimination could not be achieved.
- B. The six superoxide beds were operated connected in series with parallel selective flow control. When the 3 system blowers were actuated the head generated resulted in leakage of air ( $\sim 15$  CFM) through the closed bed butterfly valves. This leakage caused a high oxygen production rate which raised the  $\text{O}_2$  concentration to 28% before 2 blowers were disconnected. The chamber oxygen concentration subsequently reached a maximum of 30.45%. A carbon dioxide maximum level of 1.22%

was reached at the end of four days. The high oxygen concentration was generated by excessive air flow through the superoxide beds. This high flow was initiated and maintained in an attempt to remove the atmospheric contaminant which was causing crew illness.

- C. An unidentified contaminant was produced during the course of the test which caused illness of all crew members and, finally, a test abort, indicating that the catalytic oxidizer and superoxide were not effective in removing some trace contaminants.

6.1.5.2

#### MESA II

#### DEVELOPMENT

##### A. Chamber Testing

Following MESA I and prior to the MESA II 17 day pre-test, a series of unmanned chamber tests were conducted primarily to determine the cause of MESA I toxicity. A hydrogen flame and bottled carbon dioxide gas injection were used to simulate the respiratory demands of 5 men during these integrated systems tests. Chamber oxygen and carbon dioxide levels were regulated to closer limits than had been previously attained and bed yields of oxygen about equaled calculated theoretical yields.

##### B. Hydrogen Evolution Study

As a result of the hydrogen build-up noted during MESA I, a test was conducted to determine the compatibility of aluminum and sodium superoxide.

Sodium superoxide was intimately mixed with bits of .003 aluminum foil used for the bed honeycomb core. Air containing 5% CO<sub>2</sub> and at a relative humidity of 10% was cycled through the mixture for 84 hours. Carbon dioxide and water were added to the airstream to maintain the above levels. Hydrogen concentration, measured periodically, reached a maximum of 7,800 PPM (0.78%) after 72 hours and then decreased. Portions of unreacted aluminum remained in the residue after the test period.

It was concluded that anhydrous NaO<sub>2</sub> does not react with aluminum but when water vapor is added a rapid evolution of hydrogen occurs. The conversion of the hydroxide, formed initially, into carbonate deaccelerates the rate of hydrogen production. The final carbonate-bicarbonate product does not react with aluminum.

- C. Following MESA I and during the period of chamber tests prior to MESA II integration testing, the following modifications were made to the respiratory system:



The catalytic oxidizer (hopcalite) was removed from the system and redesigned as an independent subsystem (see 6.1.2).

To help eliminate the unknown contaminant that caused the MESA I abort, the following material changes were made:

<u>Original Material</u>	<u>Replacement</u>
Neoprene ducting	Silicone ducting
Polysulfide bed core sealer	Quartz fiber packing
Butyl rubber gaskets (drier)	Silicone rubber gaskets
Cadmium plated bolts (heater, beds)	Nickel plate or stainless steel bolts
Oil impregnated fiberglass filters (beds, drier)	Untreated glass wool
Plywood lithium hydroxide cabinet	Stainless steel cabinet
Fiberglass insulation (heater)	Quartz fiber
Asbestos electrical insulation	Ceramic beads

To eliminate hydrogen generation, the aluminum honeycomb core and core base sheet were replaced with 300 series stainless steel in all superoxide beds.

A thermistor wet/dry bulb unit was designed, fabricated and installed adjacent to the humidity controller sensor to check operation of the humidity control system.

The system blowers (3) were wired to separate console switches to improve air flow control.

Waste reactor gas inlet was disconnected from system.

To insure the avoidance of excessive oxygen production, the beds were disconnected from their series configuration, to be connected in progression as the bed on-stream became depleted.

#### SYSTEM TEST

Conditions for the 17-day MESA II Pretest were:

- A. Five systems beds, with thermocouples, were loaded with 4-8 mesh sodium superoxide. Beds #1 and #3 contained a total of 300 pounds of fresh (92%) oxide; beds #2, #4, and #5 contained a total of 450 pounds of used (70%) oxide from MESA I.

- B. Oxidation of hydrogen and injection of bottled carbon dioxide at measured rates simulated the respiration of 5 men in the test chamber. Corrections in rates were made during the 13 days of unmanned operation to compensate for periodic chamber occupancy by control monitors.
- C. The system configuration is shown by Figure 26, with the exception of modifications listed in C, above.

Results of the 17 day integration tests are as follows:

A. Carbon Dioxide and Oxygen Control

Oxygen concentrations ranged between the limits of 18.0% and 23.5% for the 362 hours of respiratory system operation (see Figure 27). For 61% of this time atmospheric oxygen was maintained at  $21.0 \pm 1\%$ . The time weighted average oxygen concentration was calculated as 20.70%. Carbon dioxide ranged from a minimum of 0.30% to a maximum of 1.0%. For 71% of the testing time,  $\text{CO}_2$  concentration was maintained below 0.7% (see Figure 28). The time weighted average carbon dioxide concentration was calculated as 0.62%.

B. Carbon Dioxide Absorption

Carbon dioxide absorption by lithium hydroxide ( $\text{LiOH}$ ) during the 258 hours of unmanned testing equalled about 0.78 man-day  $\text{CO}_2$  output (14 cu. ft.) and, for 92 hours of manned testing, 0.66 man-day  $\text{CO}_2$  output. Total time of absorption cabinet blower operation during the above periods were 4.1 and 6.6 hours, respectively.

Total carbon dioxide produced during the unmanned portion of the test was equivalent to 48.6 man-days of respiration. Calculation shows that the superoxide absorbed 98% of this amount. Carbon dioxide absorbed during the 4-day manned portion of the test was estimated as 350 ft<sup>3</sup>. The superoxide reaction absorbed 96.5% of this amount.

C. Superoxide Oxygen Yield

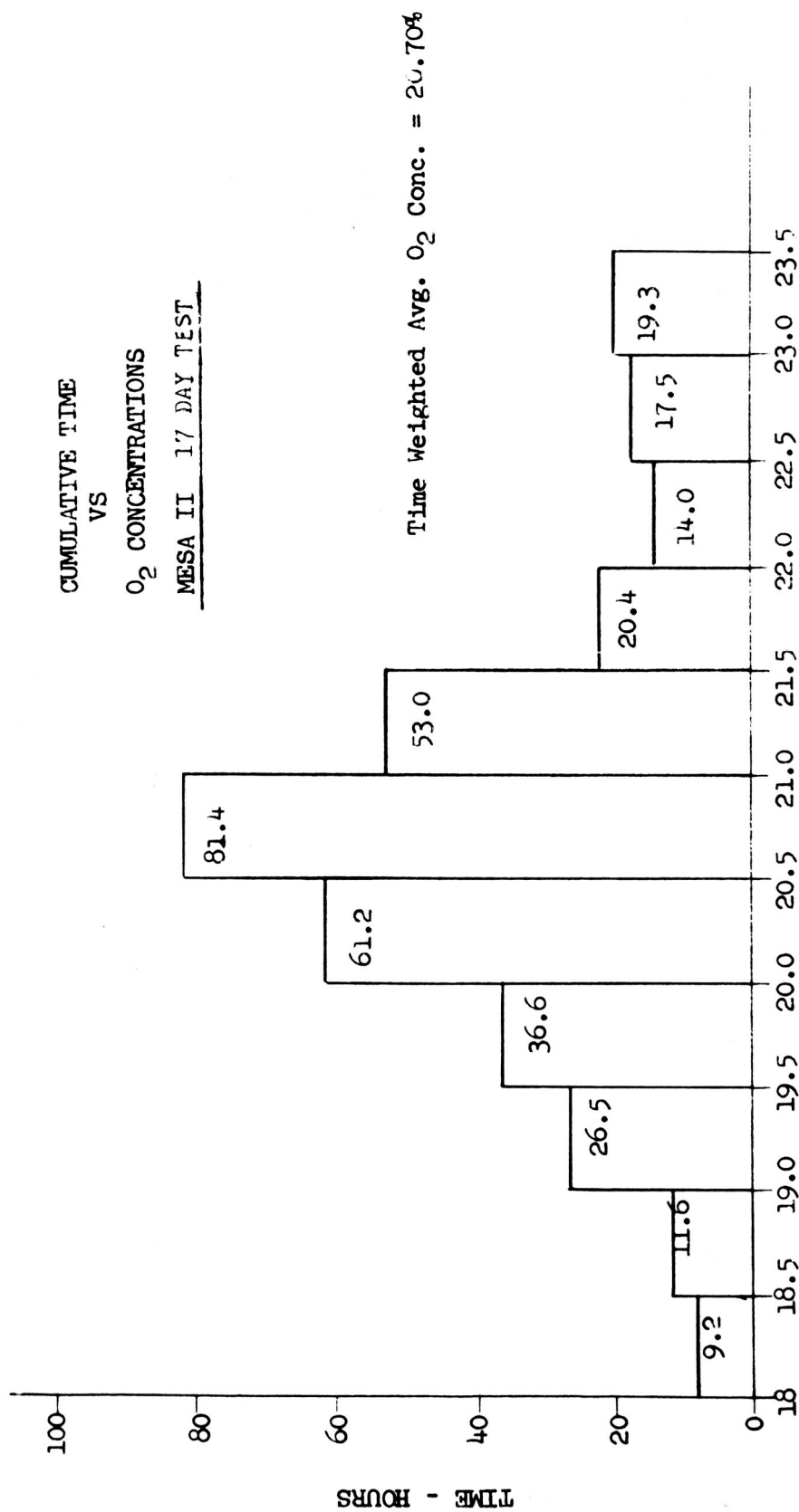
A calculation based on a total equivalent  $\text{O}_2$  usage of 1348 man-hours during operation of depleted oxide beds #1, #2, and #3 indicates an oxygen yield of 69% of theoretical or 4 days/5 men/bed compared to 5.8 days/5 men/bed.

After visual examination of the depleted beds, the low oxygen yields were attributed to the caking or fusing of the superoxide granules into clinkers of low porosity and to a general cementing of reaction surfaces. The agglomerates formed trapped or blocked unreacted oxide from the air stream. This condition was believed to have been caused by use of excessively humid air ( $.008 \text{ } \# \text{H}_2\text{O} / \# \text{dry air}$ ) during some periods of the test. Relative to oxygen and carbon dioxide limit requirements, it was concluded that with closer regulation of

CUMULATIVE TIME  
VS

O<sub>2</sub> CONCENTRATIONS

MESA II 17 DAY TEST



CHAMBER OXYGEN CONCENTRATION - %

Figure 27

CUMULATIVE TIME  
VS  
CO<sub>2</sub> CONCENTRATIONS

MESA II 17 Day Test

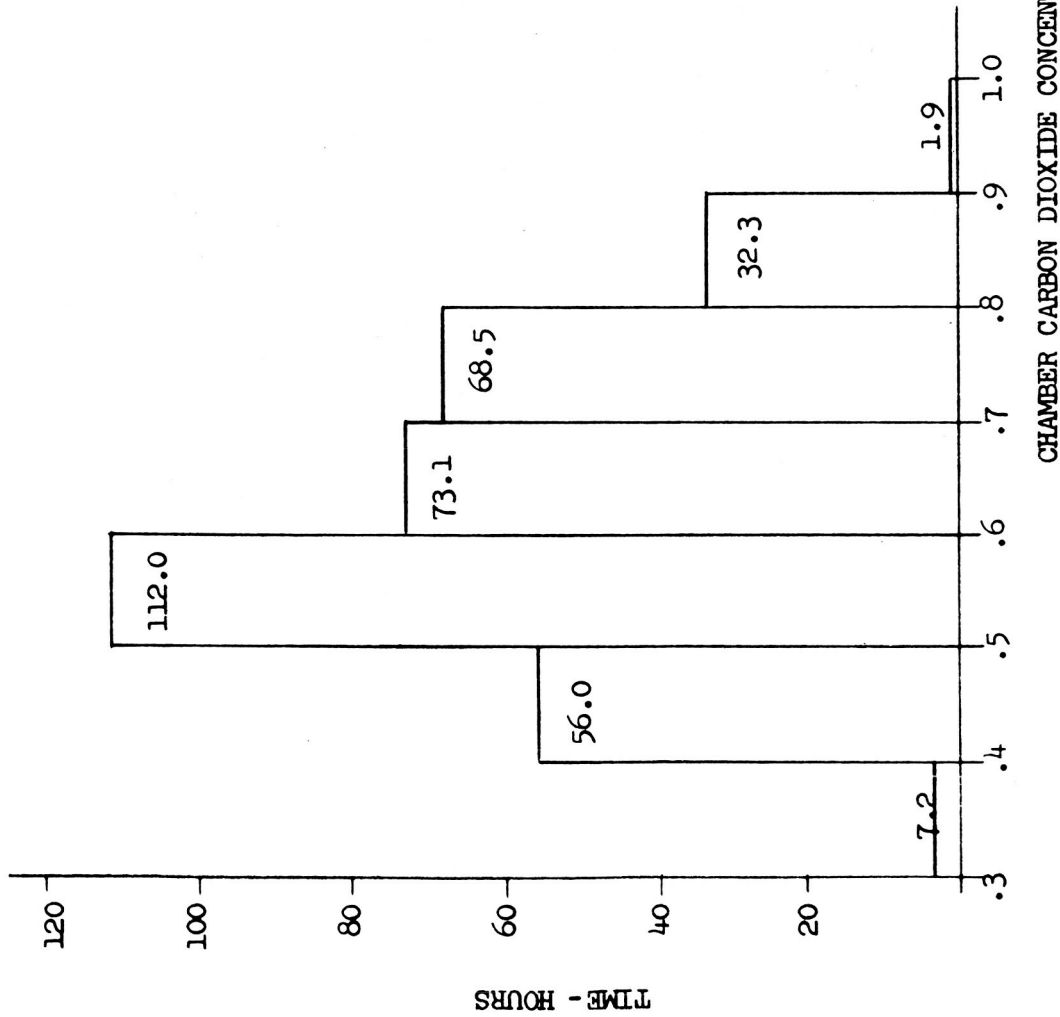


Figure 28

system air flow and judicious use of lithium hydroxide, the original limits established could be tightened to  $21.0 \pm 1.5\%$  and  $0.75\%$  maximum, respectively.

As a result of the above, a laboratory experiment was designed to show qualitatively the degree of deliquescence or "caking" that is associated with the final reaction products of sodium superoxide.

Respiratory system bed conditions were simulated relative to bed depth and air velocity by use of a 6-inch-high column of  $\text{NaO}_2$  in a 1-inch-diameter glass tube subjected to an air flow rate of 0.5 liter/minute. The dry bulb temperature of the air varied from  $70^\circ$  to  $75^\circ\text{F}$  and the relative humidity between 40 and 50%. Air flow with a  $\text{CO}_2$  concentration of 1.0% was maintained for two days.

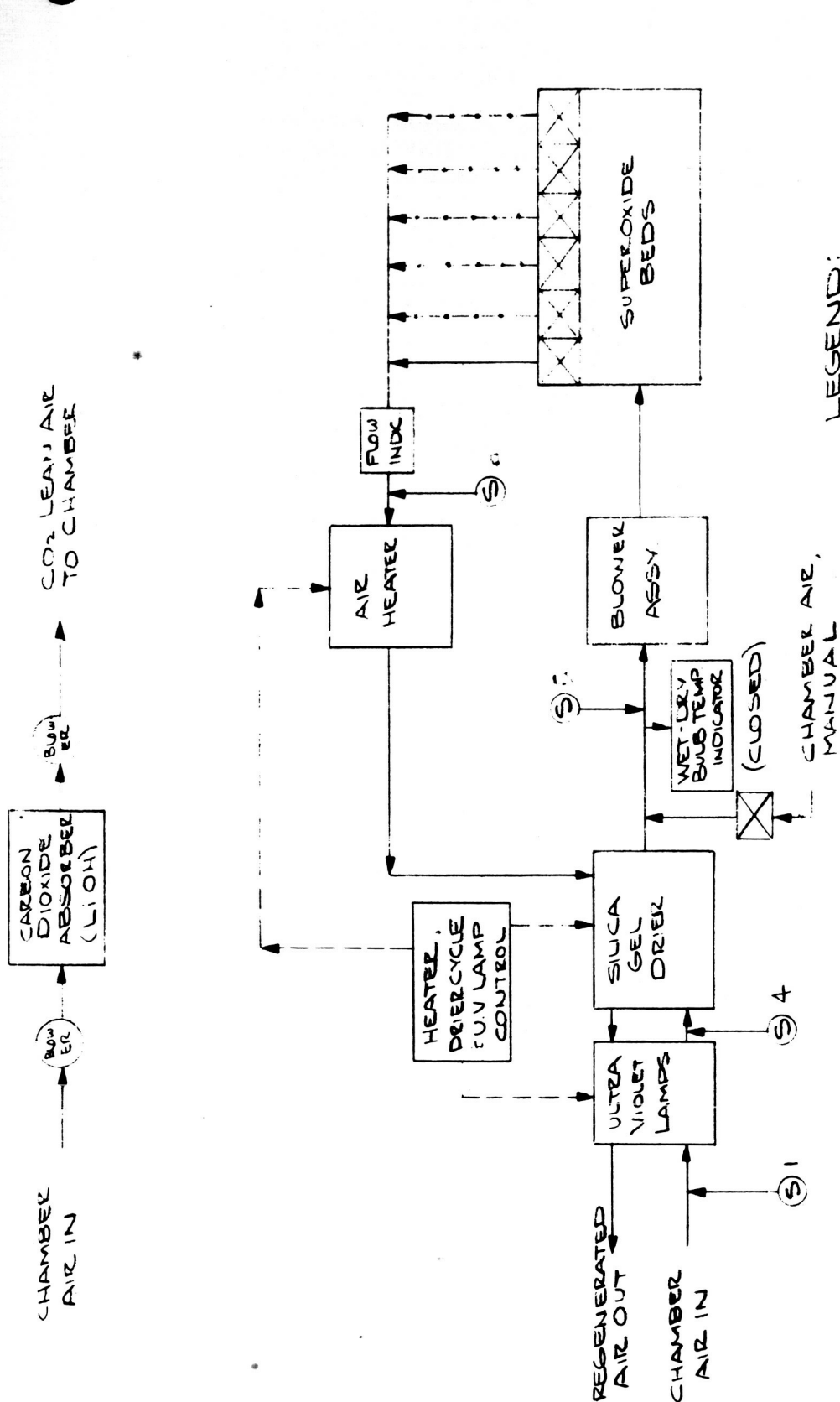
During the first nine hours of the test, the superoxide changed color from yellow to white with no observable change in granule form. Granule size remained constant for about 40 hours. At this time, the material at the exit end of the tube became moist and fusing of granules occurred.

It was concluded that under nominal operating conditions, sodium superoxide will not liquify or form a paste, however, a limited amount of caking or fusing of the reacted granules will occur.

After assessment of the 17 day MESA II pre-test results, the humidity control system was eliminated from the system because of unreliability and the drier humidity regulating servo valve was converted to a manual valve. The final system configuration before start of the 30 day MESA II test is shown by Figure 29

For the 30 day manned test the following conditions were used:

- A. Six system beds, containing a total of 912 pounds of 91.4% pure, 4-8 mesh, sodium superoxide, were mounted in the chamber with thermocouples installed in the bottom center and bottom corner of each bed. Bed temperatures were continuously recorded every 15 minutes. Each bed contained  $152 \pm 8$  pounds of oxide. Beds were installed disconnected and with ports plugged.
- B. Six canisters of anhydrous lithium hydroxide were loaded and sealed in polyethylene bags. Each canister contained about 10.5 pounds of  $\text{LiOH}$ . Two of the canisters were installed in the  $\text{CO}_2$  absorption cabinet.
- C. Analysis and control of system performance was done by means of externally located gas analysis instruments that indicated carbon dioxide and oxygen concentrations continuously in the chamber and at one of the system taps (Fig. 29) every 25 mins.



MESA II RESPIRATORY SYSTEM  
FLOW DIAGRAM

FIG 29

The first oxide bed was plumbed into the respiratory system approximately 15 hours after the chamber was sealed. The delay was required to obtain an atmospheric analysis base line and respiratory quotient data. When the first oxide bed became depleted, the second bed was connected to the first bed and to the flow control manifold. This process was repeated, as beds were exhausted, until all six beds were connected in series.

As each bed was added, the previous beds (2 max.) were left on-stream in order to continue absorbing carbon dioxide and evolving residual oxygen. Days of adequate oxygen generation from each bed were:

<u>Bed Number</u>	<u>Days of Operation</u>
1	4.29
2	5.37
3	5.79
4	5.75
5	5.96
6	<u>2.21</u> - Partially used

Total 29.37 Days

Operation of the lithium hydroxide CO<sub>2</sub> absorber to maintain carbon dioxide concentrations below 0.75% was as follows:

<u>No. of NaO<sub>2</sub> Beds Connected</u>	<u>Hours of Li OH Use</u>
0	9.5
1	19.5
2	1.2
3	4.5
4	4.7
5	7.0
6	<u>0.2</u>

Total 46.6 Hours

The first set of two canisters was exhausted before connection of bed #3 (30.2 hours of operation). The second cabinet charge (2 canisters) used during operation of NaO<sub>2</sub> beds #3 through #6, logged 16.4 hours of operation.

The range of system parameters established during operation were:

	<u>Range</u>	<u>Nominal</u>
Bed Temperature	96°F-235°F	160°F
Indicated Air Flow Rate	32 CFM	28 CFM
Humidity of Air to Beds	.0016-.0080 $\frac{\text{Lbs.H}_2\text{O}}{\text{Lb Dry Air}}$	.0042 $\frac{\text{Lbs.H}_2\text{O}}{\text{Lb Dry Air}}$
Temperature of Air to Beds	90°F-126°F	110°F

From the 23rd day of the test to the end, air humidity to the beds increased from an average of .0045  $\frac{\text{H}_2\text{O}}{\text{Dryair}}$  to an average of .0058  $\frac{\text{H}_2\text{O}}{\text{Dryair}}$ , indicating contamination or exhaustion of the silica gel.

Results of the 30 day integration tests are as follows:

#### A. Carbon Dioxide and Oxygen Control

During the 29.37 days of respiratory system operation, oxygen and carbon dioxide concentration ranges and time weighted average concentrations, Figures 30 and 31, were:

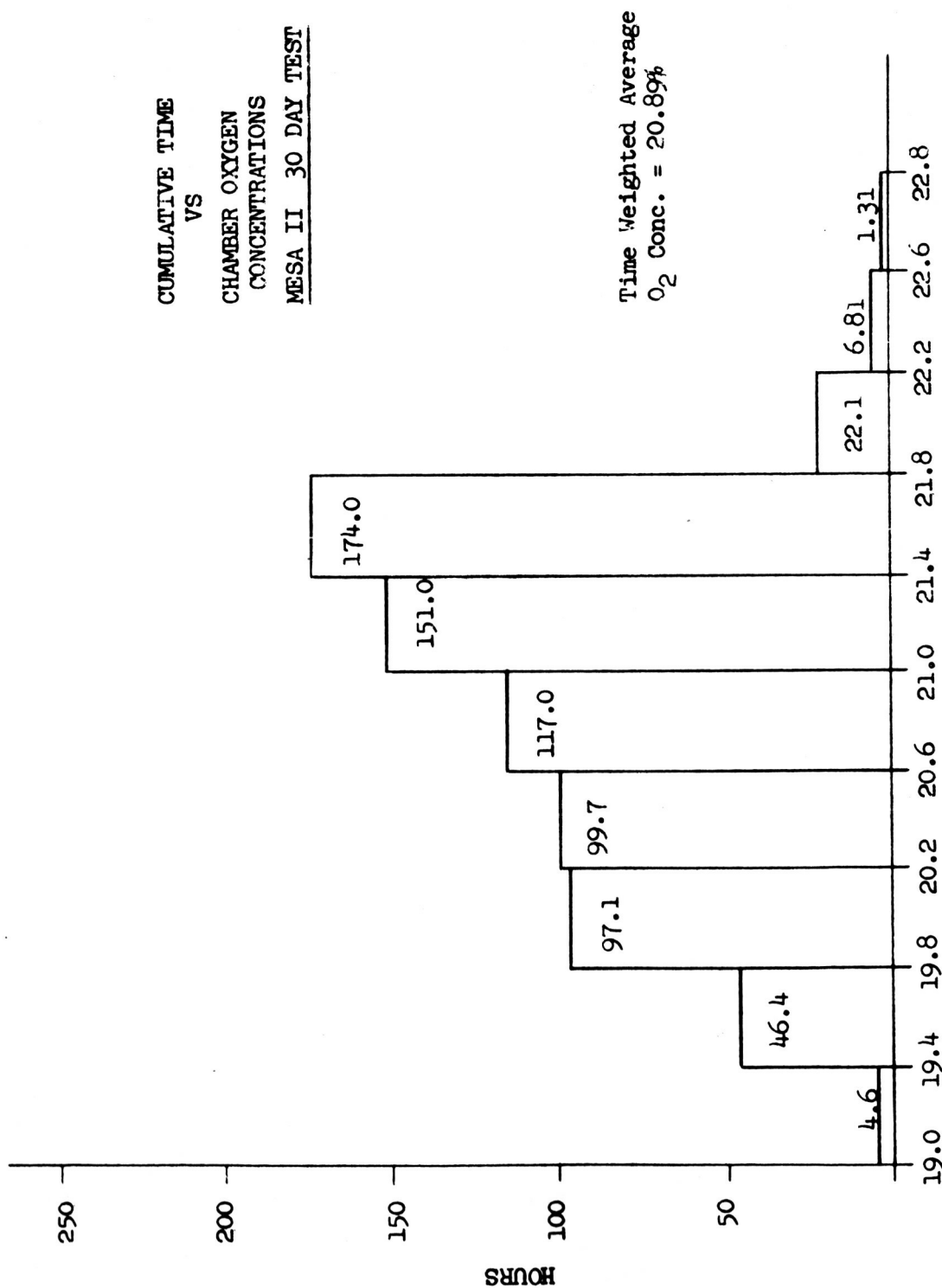
	<u>Range, %</u>	<u>Average (Time Weight), %</u>
Oxygen	19.0 - 22.8	20.89
Carbon Dioxide	0.30- 0.87	0.717

Oxygen concentration was maintained at the required limit of  $21.0 \pm 1.5\%$  for 97.3% of the test time. Carbon dioxide concentration was maintained below the required limit of 0.75% for 91.5% of the test time.

#### B. Superoxide Oxygen Yield

The first five beds supplied the oxygen requirements of five men plus the waste reactor (equivalent to 0.17 man, see 6.1.3.2) for a period of 27.16 days. The yield of oxygen from sodium superoxide during this period was calculated as 96.7% of theoretical, or 2730 ft<sup>3</sup> (760 MM and 76°F). This value, corrected for chamber leakage, pressure and oxygen concentration differentials is equivalent to a usage of 2.13 lbs/man-days and an average bed production rate of .096 CFM. Calculations were based on the chemical analysis of bed #3, assumed as typical, see Table 1. A graph of oxygen production rate by bed #3 versus time (Fig.32), based on gas analysis data obtained during operation of bed #3, gives an average production rate of 0.106 CFM O<sub>2</sub> and also indicates the control measures required.





CHAMBER OXYGEN CONCENTRATION - %

Figure 30

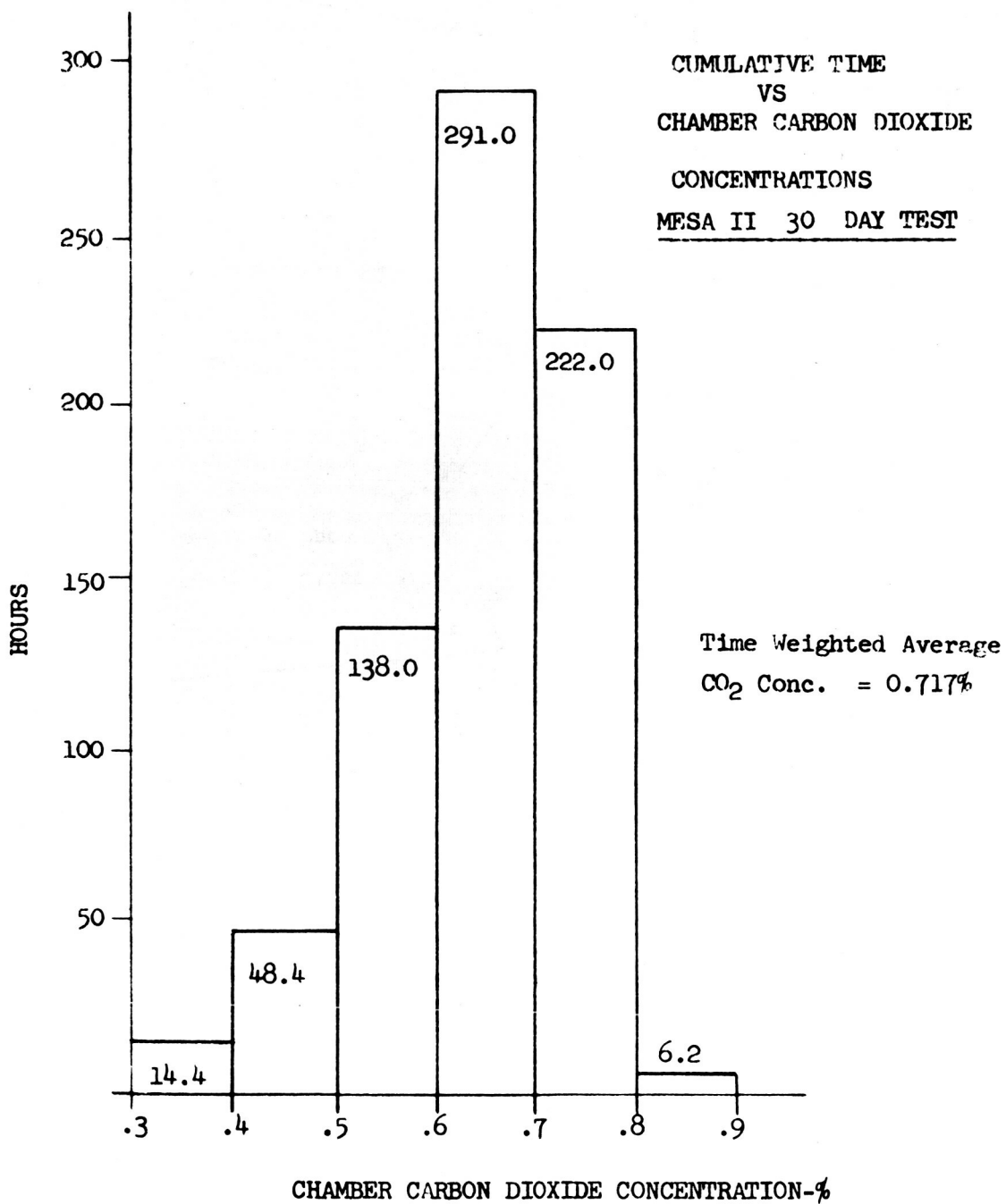


Figure 31



### C. Carbon Dioxide Absorption

The carbon dioxide absorbed by all oxide beds during the 29.37 days of respiratory system operation was calculated as 3100 FT<sup>3</sup> (760 MM & 76°F), based on bed #3 reaction products analysis (Table 1). Supplementary carbon dioxide absorption by lithium hydroxide was calculated from gas analysis data as about 187 FT<sup>3</sup> or 5.7% of the total carbon dioxide evolved by 5 men plus the waste reactor. Absorption of CO<sub>2</sub> by lithium hydroxide relative to bed usage was:

<u>Superoxide Beds On-Stream</u>	<u>Cu. Ft. of CO<sub>2</sub> Absorbed by Li OH</u>
1	78.0
1 and 2	12.5
1, 2 and 3	34.0
2, 3 and 4	27.2
3, 4 and 5	34.2
4, 5 and 6	1.4
TOTAL	187.3 Ft <sup>3</sup>

Total CO<sub>2</sub> absorbed was calculated as equivalent to a crew + reactor production rate of 2.44 lbs/man-day.

### D. Respiratory Quotient Analysis

Calculations, derived from the gas analysis data during the period before respiratory system start-up (14.5 hours), give a crew respiratory quotient ( $\frac{\text{Vol. CO}_2 \text{ evolved}}{\text{Vol. O}_2 \text{ absorbed}}$ ) of 0.635. The oxygen and carbon dioxide rates of absorption and evolution were calculated as 0.100 CFM and 0.0635 CFM, respectively, during this "base line" period.

The respiratory system R.Q. derived from the analysis of bed #3 reaction products, Table 1, was calculated as 0.77. Correction of the oxygen volume obtained for chamber leakage, pressure and concentration differentials and correction of the carbon dioxide volume for the amount absorbed by lithium hydroxide results in an average crew R.Q. of 0.83.

### E. Bed Temperatures

A progressive maximum temperature front was recorded by the gang thermocouples mounted in one of the center cells of bed #1. Peak bed temperatures were attained at lower bed depths, as shown by Figure 33, as the reaction of superoxide progressed with time.

It was concluded that the respiratory system was one of the most successful of the Life Support systems tested because of its ability to meet specified atmospheric requirements, ease of control, reliability and simplicity of operation.

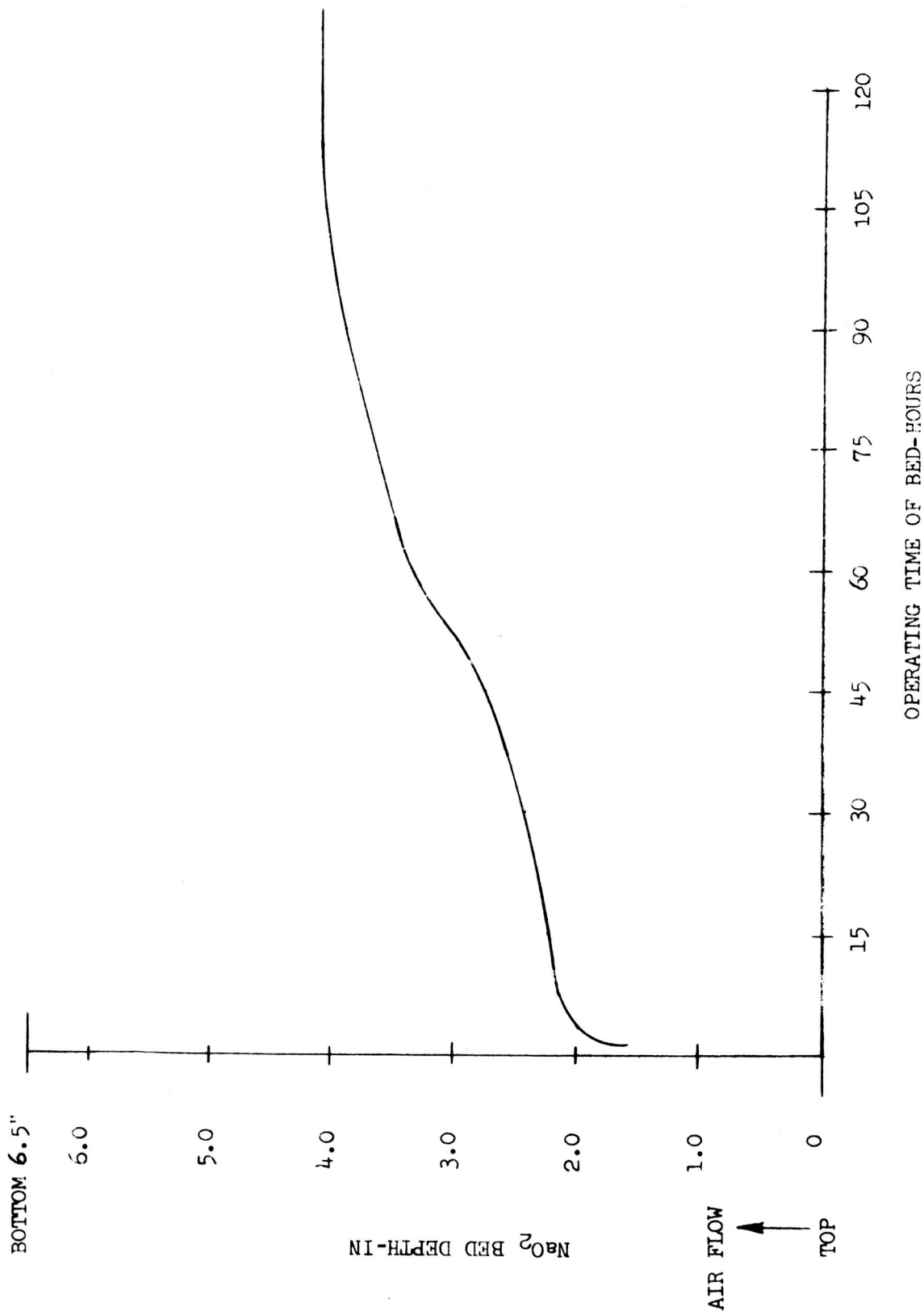


FIGURE 33  
 MAXIMUM  $\text{Na}_2\text{O}_2$  TEMPERATURE LOCATION  
 VERSUS  
 TIME OF OPERATION

RECOMMENDATIONS

The respiratory system could be improved functionally by:

- A. Improved valving to permit operation of all beds in series with parallel selective flow control, eliminating the need to connect beds during operation because of valve leakage.
- B. Added air flow control instrumentation to indicate flow rates from each bed and flow rate into and from the system, permitting finer regulation of reaction rates.
- C. Incorporation of heat exchangers in system air stream to regulate temperature of oxide reaction.
- D. Use of more efficient filters with lithium hydroxide.

Further studies are required to determine the optimum conditions relative to air temperature and humidity, for conversion of carbonate to bicarbonate for the purpose of improving carbon dioxide absorption rate by the superoxide reaction products. Determination of the unknown gas evolved in the chemical analysis of bed #3 reaction products (Table 1 ) is desirable.

TABLE 1

CHEMICAL ANALYSIS OF SUPEROXIDE BED #3 REACTION PRODUCTS				
Sample Location	Total Gas Evolved ml/gm	CO <sup>2</sup> ml/gm	O <sub>2</sub> ml/gm	Unknown ml/gm
Center Bottom #1	210.5	184.7	9.0	16.8
Center Bottom #2	209.4	194.7	11.4	3.3
Corner Bottom	228.3	214.3	0.2	13.8
Corner Top			10.6	
Center Top #1			18.1	
Center Top #2			20.2	

Sample Location	% Na <sub>2</sub> CO <sub>3</sub>	% Na H CO <sub>3</sub>	% NaOH
Center Bottom #1	88.7	0	7.6
Center Bottom #2	85.9	0	7.6
Corner Bottom #1	90.6	6.8	0
Corner Bottom #2	92.9	3.6	0
Center Top #1	97.7	0	0
Center Top #2	96.1	1.6	0
Corner Top #1	91.4	7.6	0
Corner Top #2	92.8	4.9	0

Average Composition	%
Na <sub>2</sub> CO <sub>3</sub>	92.0
NaH CO <sub>3</sub>	3.0
NaOH	1.9
O <sub>2</sub>	1.3
Unknown	1.8
	<hr/> 100.0

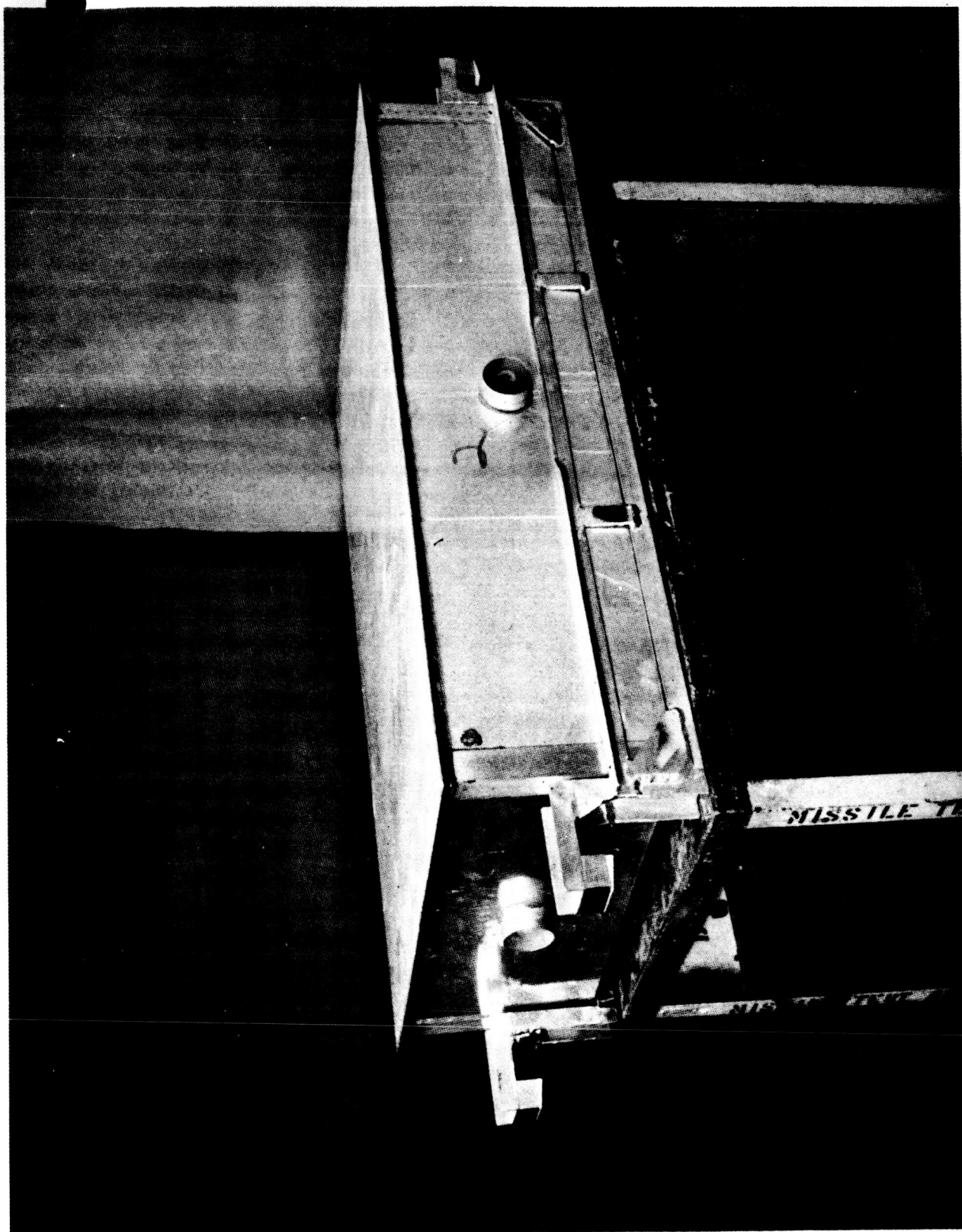


Photo 9: RESPIRATORY SYSTEM SUPEROXIDE BED ASSEMBLY (TYPICAL)



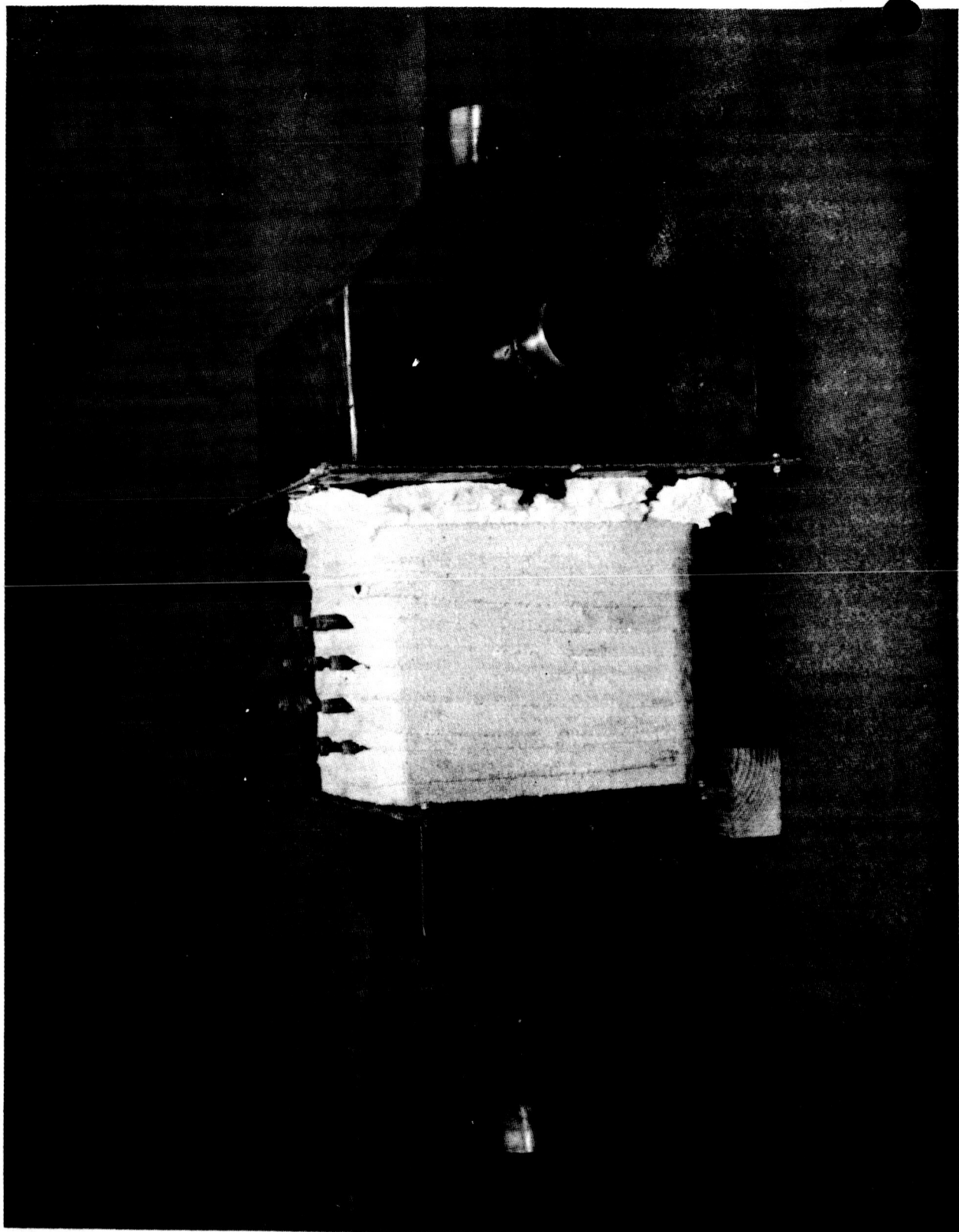


Photo 10: RESPIRATORY SYSTEM AIR HEATER

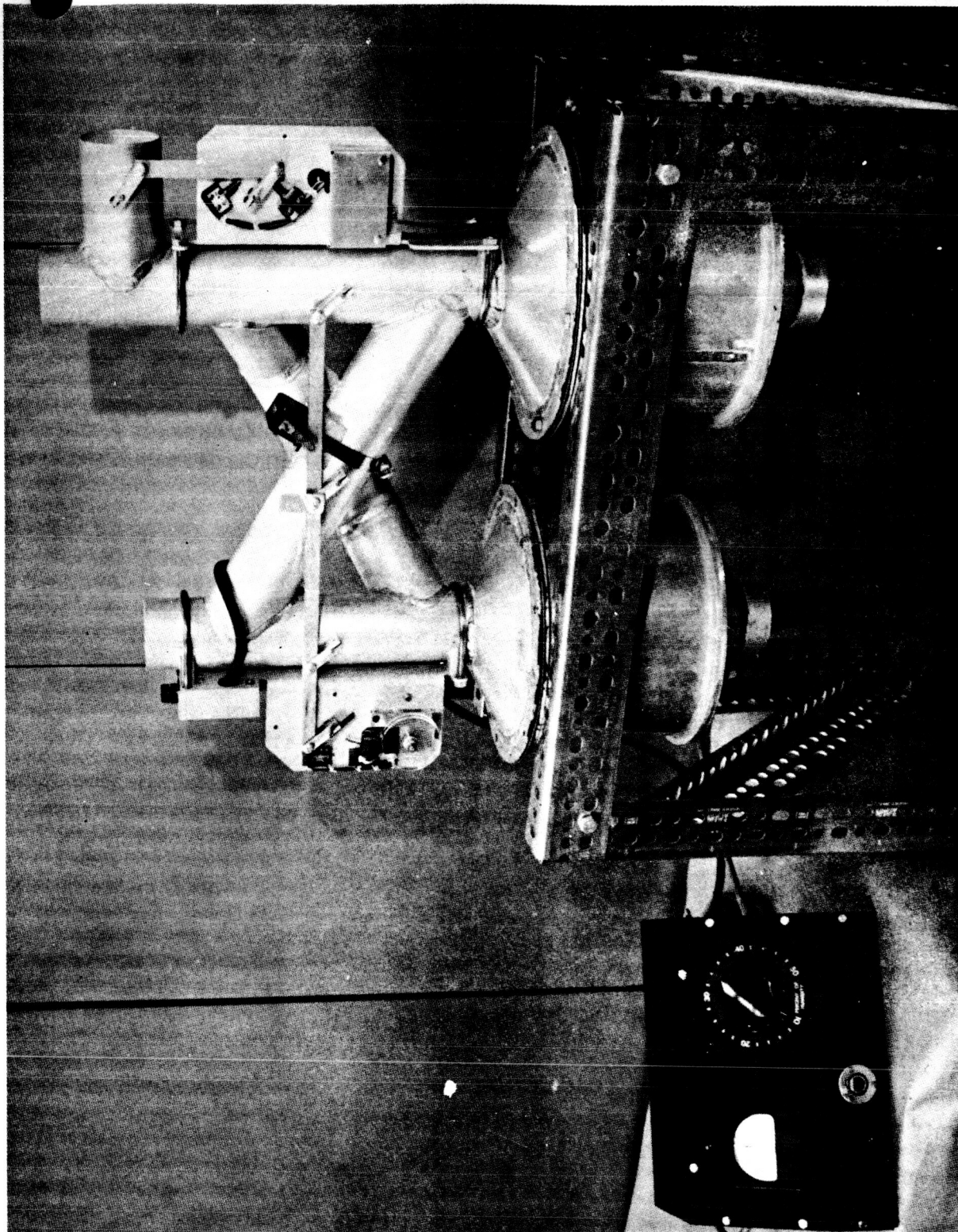


Photo 11: RESPIRATORY SYSTEM AIR DRIER UNIT  
(Before Elimination of Servo By-Pass)

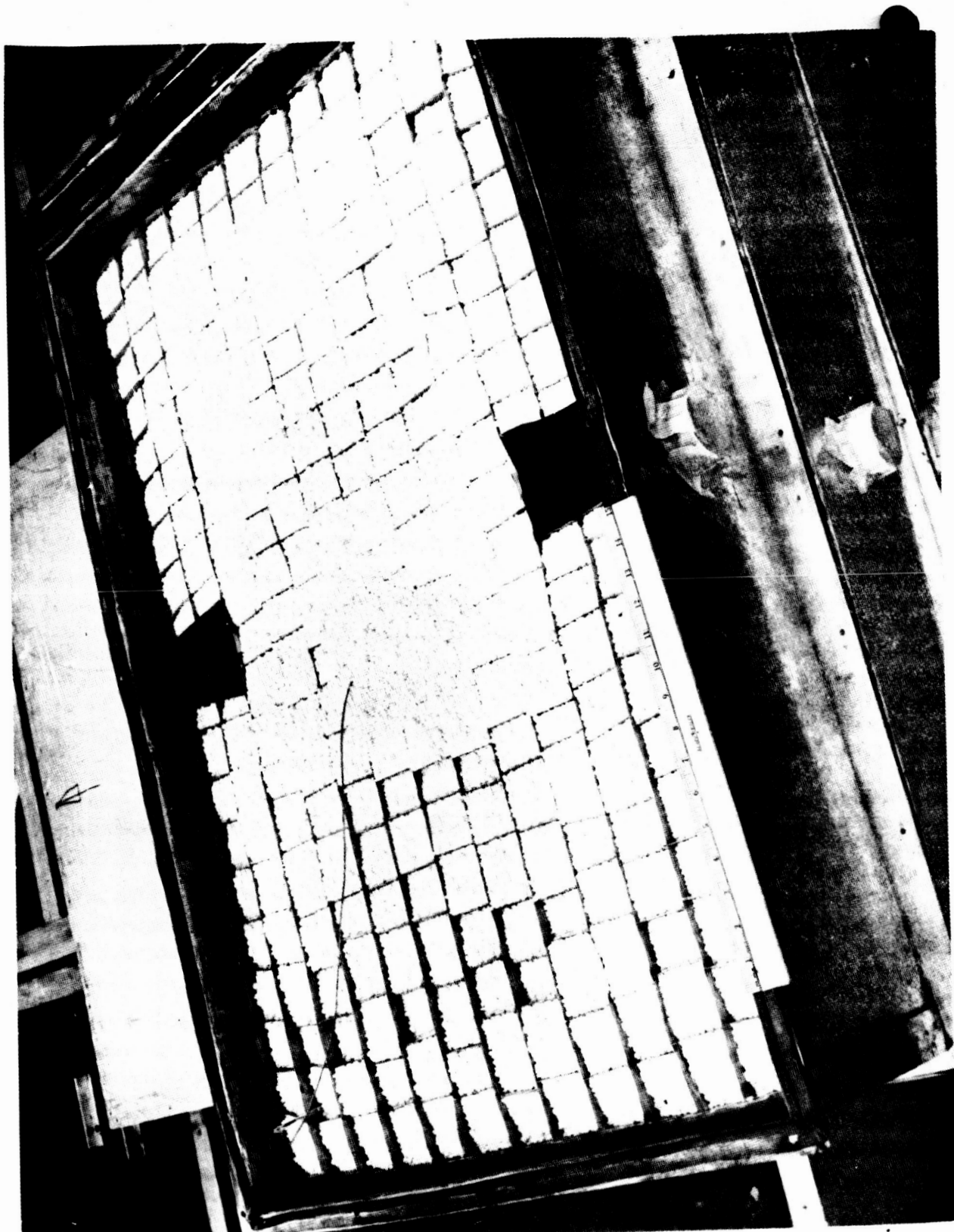


Photo 12: SUPEROXIDE BED AFTER 30 DAY TEST



BED #3  $\text{NaO}_2$   
CENTER-TOP 3"  
MESA II



BED #3  $\text{NaO}_2$   
CORNER-TOP 3"  
MESA II



BED #3  $\text{NaO}_2$   
CENTER-BOTTOM 3"  
MESA II



BED #3  $\text{NaO}_2$   
CORNER-BOTTOM 3"  
MESA II

Photo 13: TYPICAL SAMPLES OF SUPEROXIDE BED REACTION PRODUCTS



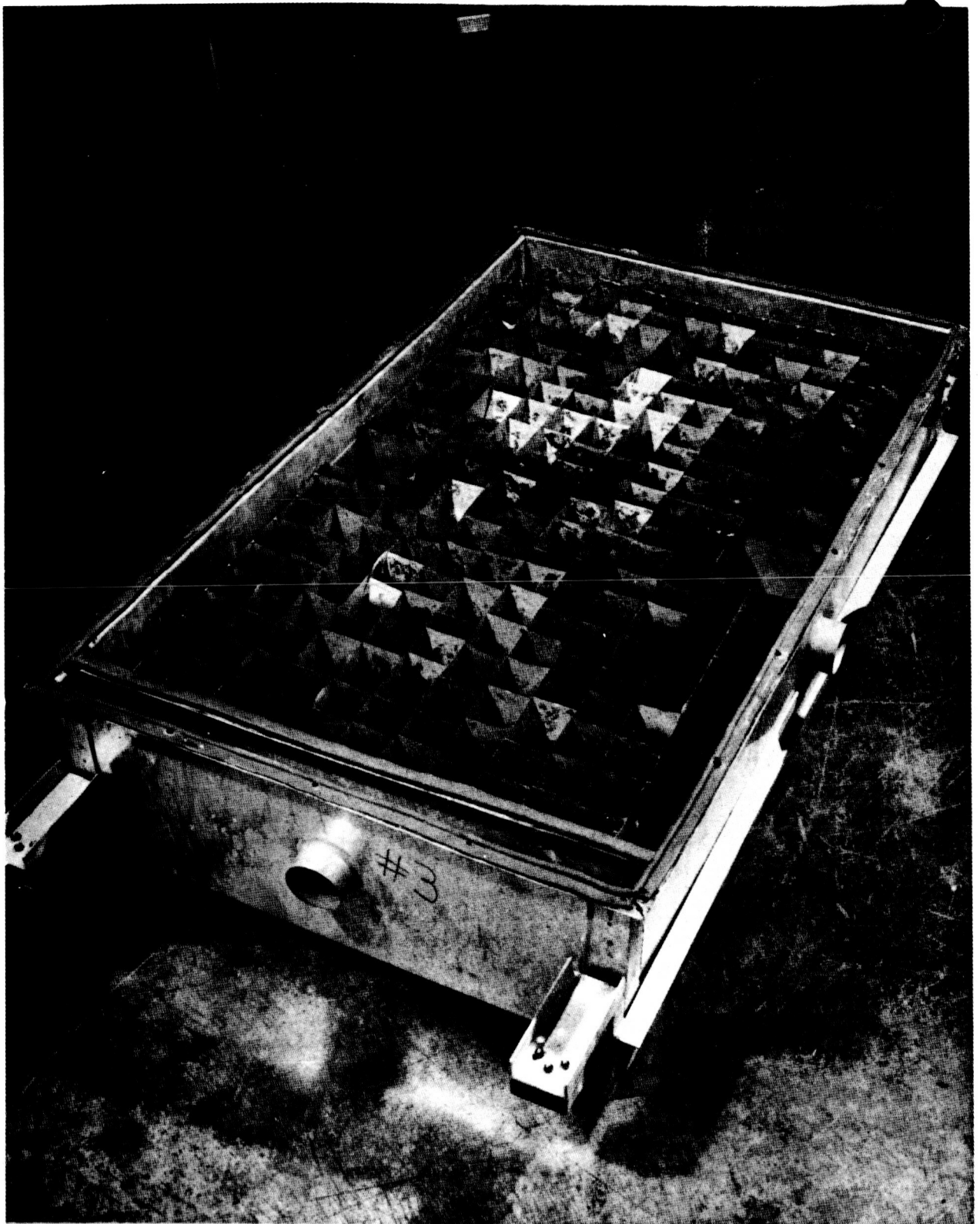


Photo 14: TYPICAL SUPEROXIDE BED ASSEMBLY AS CLEANED AFTER 30 DAY TEST

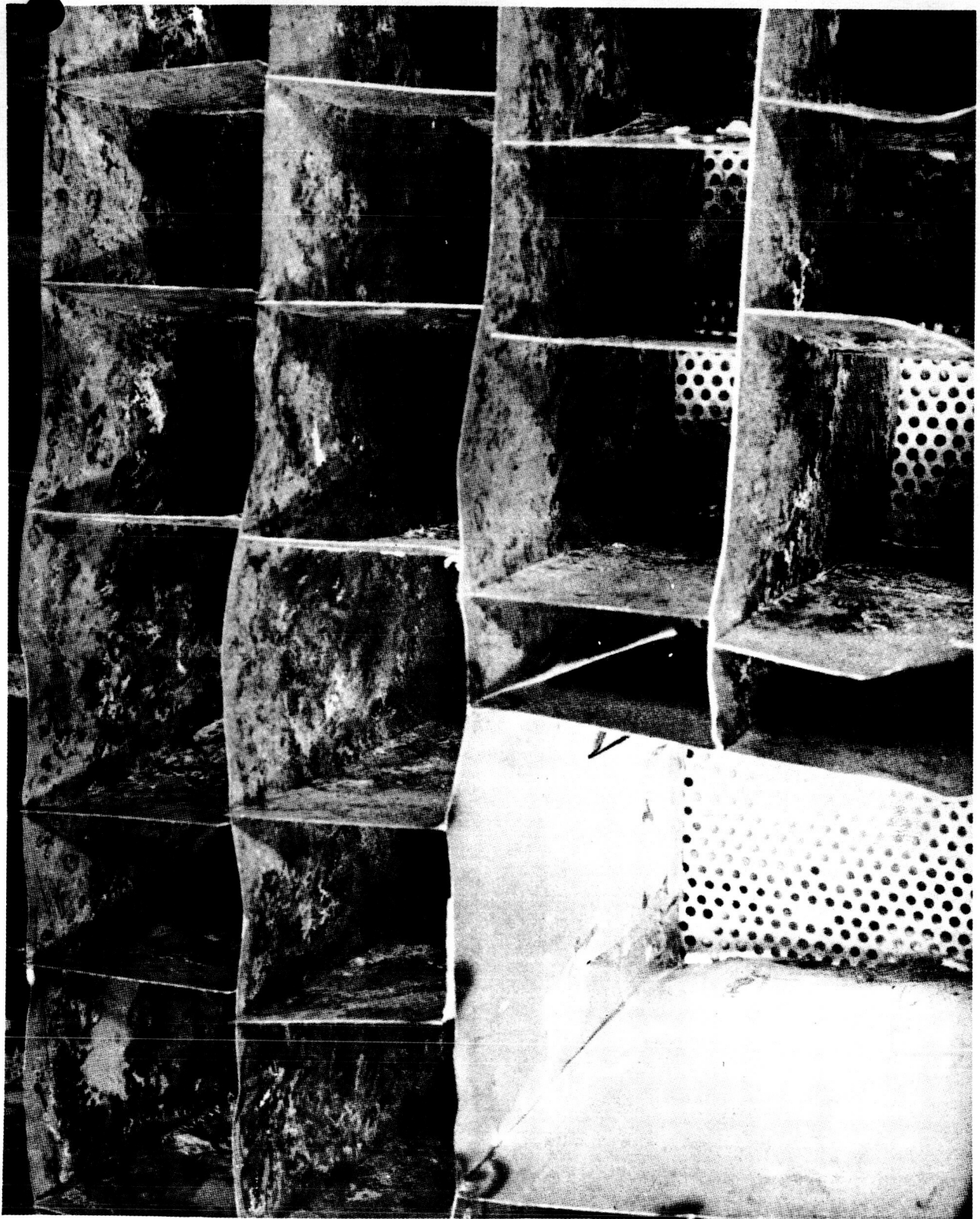


Photo 15: INTERIOR OF CLEANED SUPEROXIDE BED AFTER 30 DAY TEST

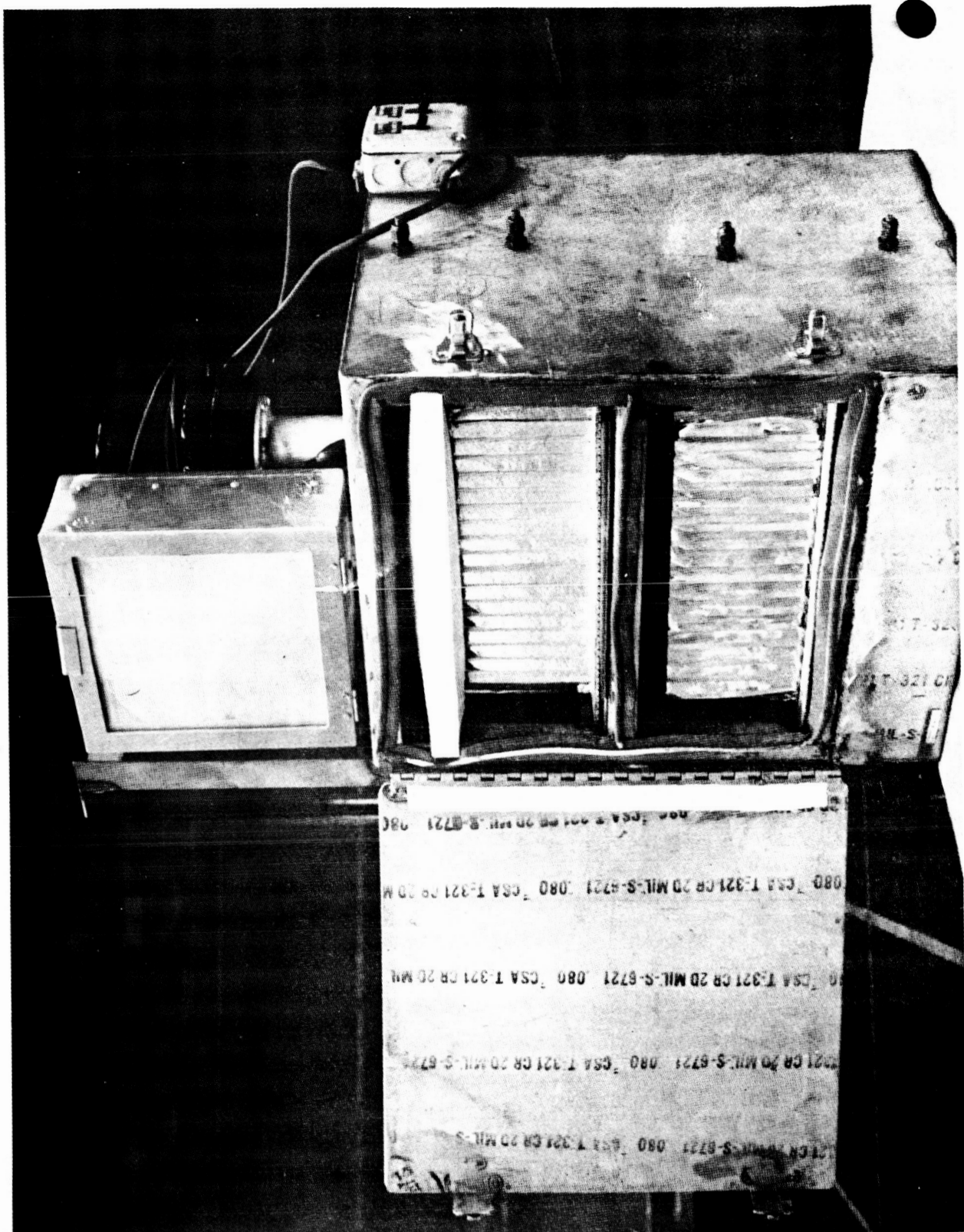


Photo 16: LITHIUM HYDROXIDE CO<sub>2</sub> ABSORBER UNIT

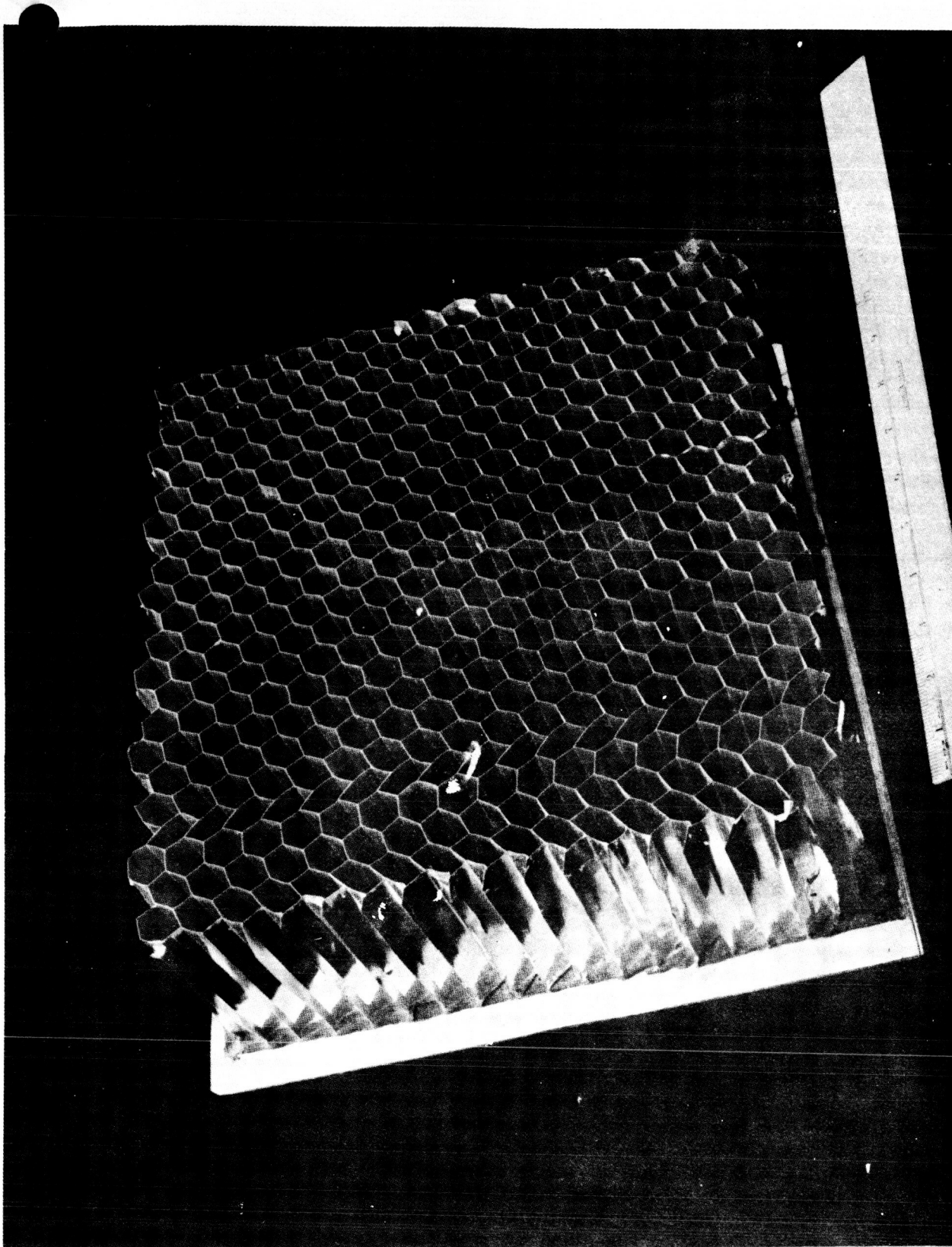


Photo 17: LITHIUM HYDROXIDE CANISTER



## 6.1.6

## TEMPERATURE AND HUMIDITY CONTROL SYSTEM

### 6.1.6.1

### MESA I

#### DEVELOPMENT

The basic requirement was to provide an environment within the test chamber that would be comfortable for the subjects. To meet this requirement the temperature and humidity control system recycled the cabin air through a heat exchanger to reduce the temperature and relative humidity of the air.

The detail requirements were as follows:

- A. Maintain the chamber air temperature at  $75 \pm 10^{\circ}\text{F}$ .
- B. Maintain the chamber relative humidity at  $50 \pm 10\%$ .

The design heat loads were as follows:

- A. 8650 Btu/hr constant load.
- B. 19,550 Btu/hr intermittent load.

The temperature and humidity control system consisted of a liquid-to-air type heat exchanger, an air-distribution fan assembly, return air filters that were cut from an oil-impregnated fiberglass material and the necessary ducts to provide for proper distribution of the air. The cabin air and the shower air were passed through the heat exchanger where the air was cooled and the moisture was condensed out of the air. The condensate was pumped to the water system for treatment and the air distributed to the cabin.

The cooling liquid was a mixture of 50% glycol-50% water that was cooled by a refrigeration system located outside the test chamber. The final configuration is as shown by block diagram Fig. 34.

#### SYSTEM TESTS

During the course of the 2 day pre-test temperature surveys and minor adjustments were made to balance system. System performance during this test as well as the 4 1/2 day aborted test was satisfactory.

### 6.1.6.2

### MESA II

#### DEVELOPMENT

Prior to the start of the MESA II tests, redesign of other subsystem components increased the design heat load to a mean (average) calculated heat load of 22,867 Btu/hr.

The increased heat load increased the cooling requirements of the system. To provide for the increased cooling required, the size of the glycol distribution lines were increased.

Because of the contaminant problem in MESA I (see Section 6.2.1) the fiberglass inlet filters were replaced by a 1000 SCFM Mine Safety Appliance Co. "CBR" filter. As the CBR filter increased the pressure drop through the system, the air distribution fan assembly was replaced with one that would provide the required air flow at the higher pressure drop. This increased the noise level of the system.

The sub-system was tested in the laboratory with different air distribution fan assemblies to determine which would provide the quietest system.

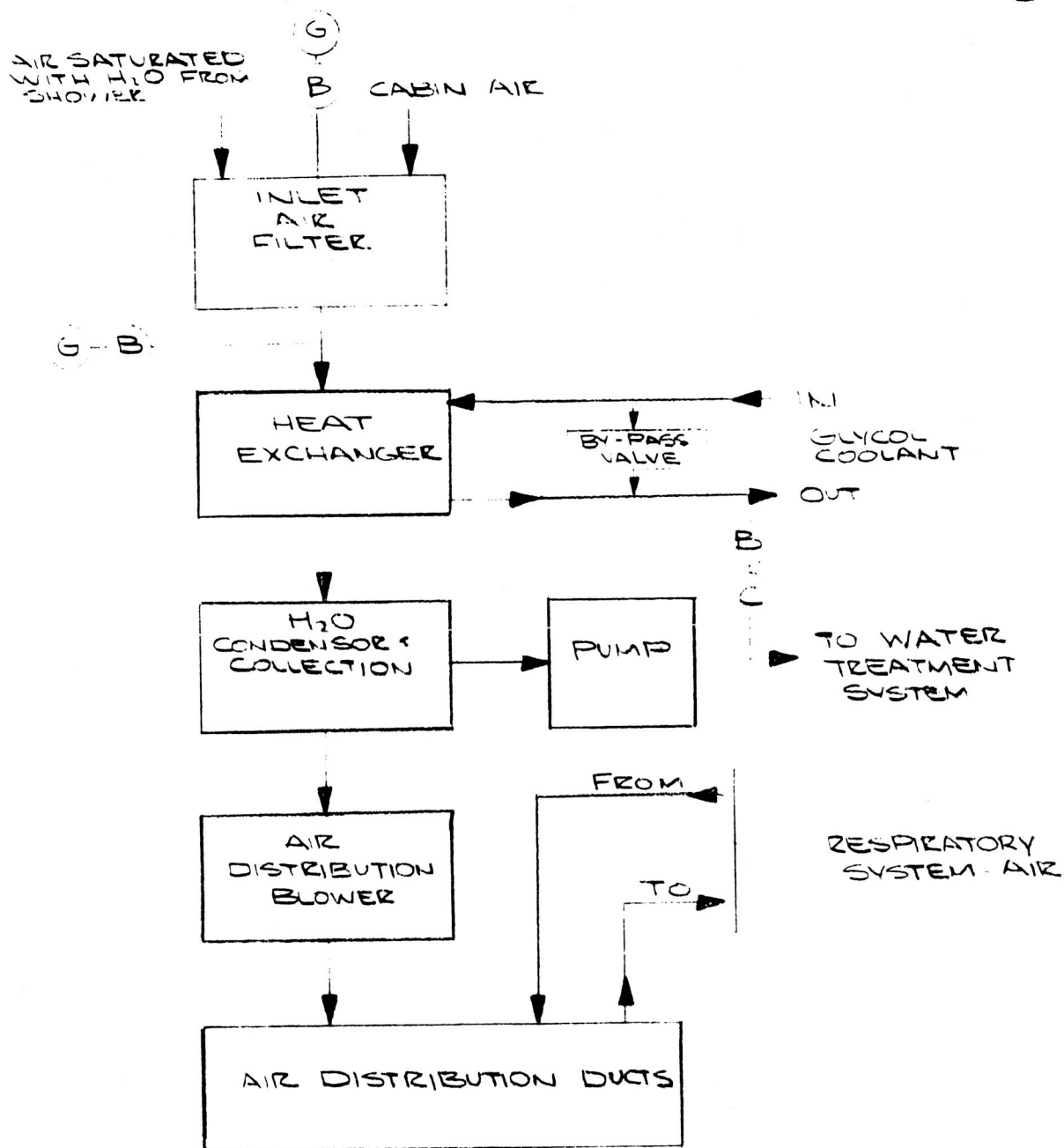
The selected system was installed in the chamber and noise level tests were conducted. As a result of these tests a muffler was designed for installation in the air distribution line downstream of the fan. The fan was enclosed in an insulated box and the inlet ducting was insulated from the chamber wall. This reduced the noise in the chamber to an acceptable level.

The final configuration is as shown by block diagram No. 38.

#### SYSTEM TESTS

The temperature and humidity control system performed in a satisfactory manner during the 17-Day Test.

The system performed in a satisfactory manner during the 30-Day Manned Test. The average relative humidity was 41% and the average cabin temperature was 77°F. The humidity underflow pump tubing was replaced four times during the test as required by the maintenance schedule and there were no failures of the system.



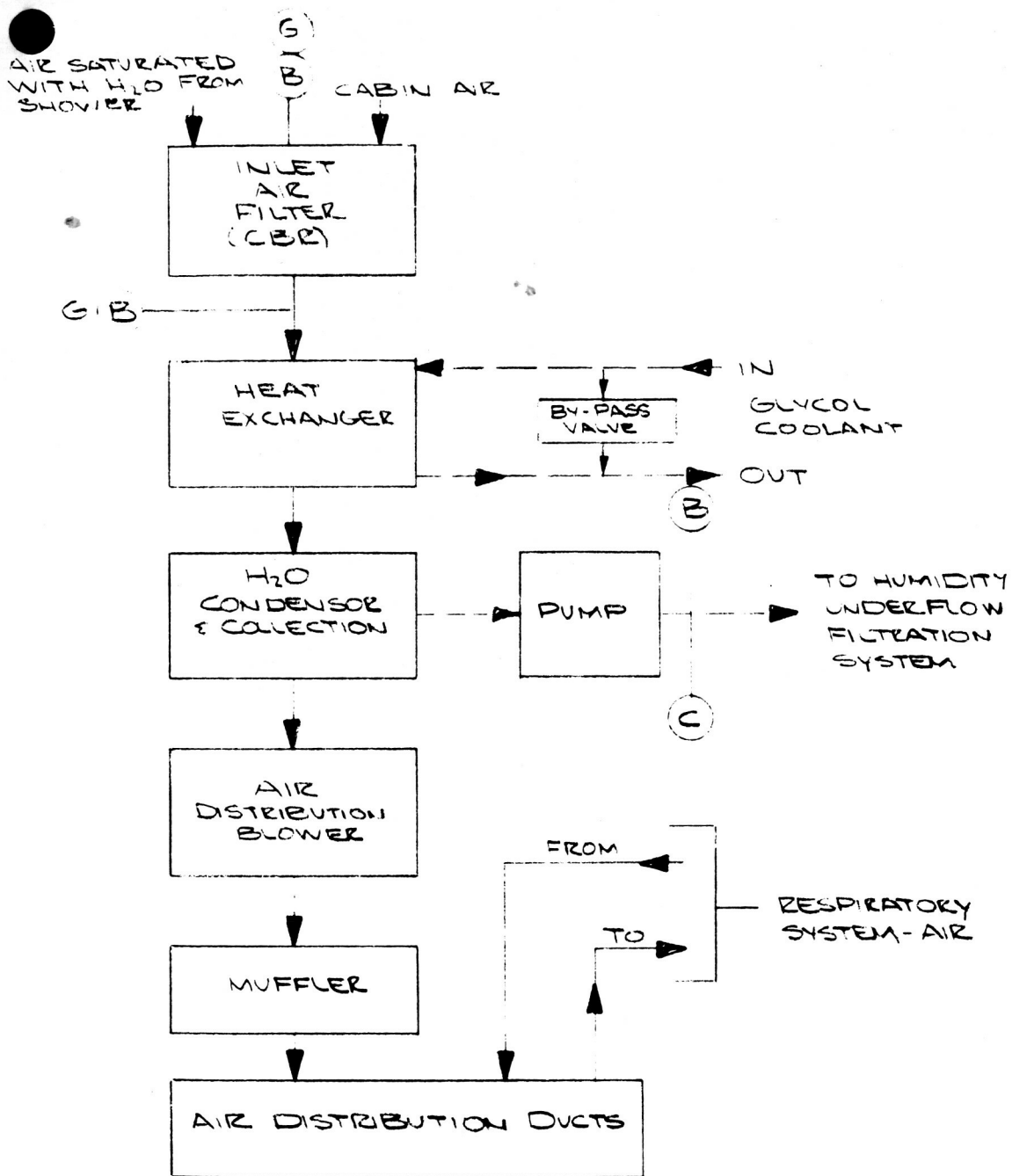
LEGEND:

- G GAS SAMPLING
- C CHEMICAL SAMPLING
- B BACTERIA SAMPLING

TEMPERATURE & HUMIDITY CONTROL SYSTEM

MESA I

FIG. 34



LEGEND:

- G) GAS SAMPLING
- C) CHEMICAL SAMPLING
- B) BACTERIA SAMPLING

TEMPERATURE & HUMIDITY CONTROL SYSTEM

MESA II

FIG. 35

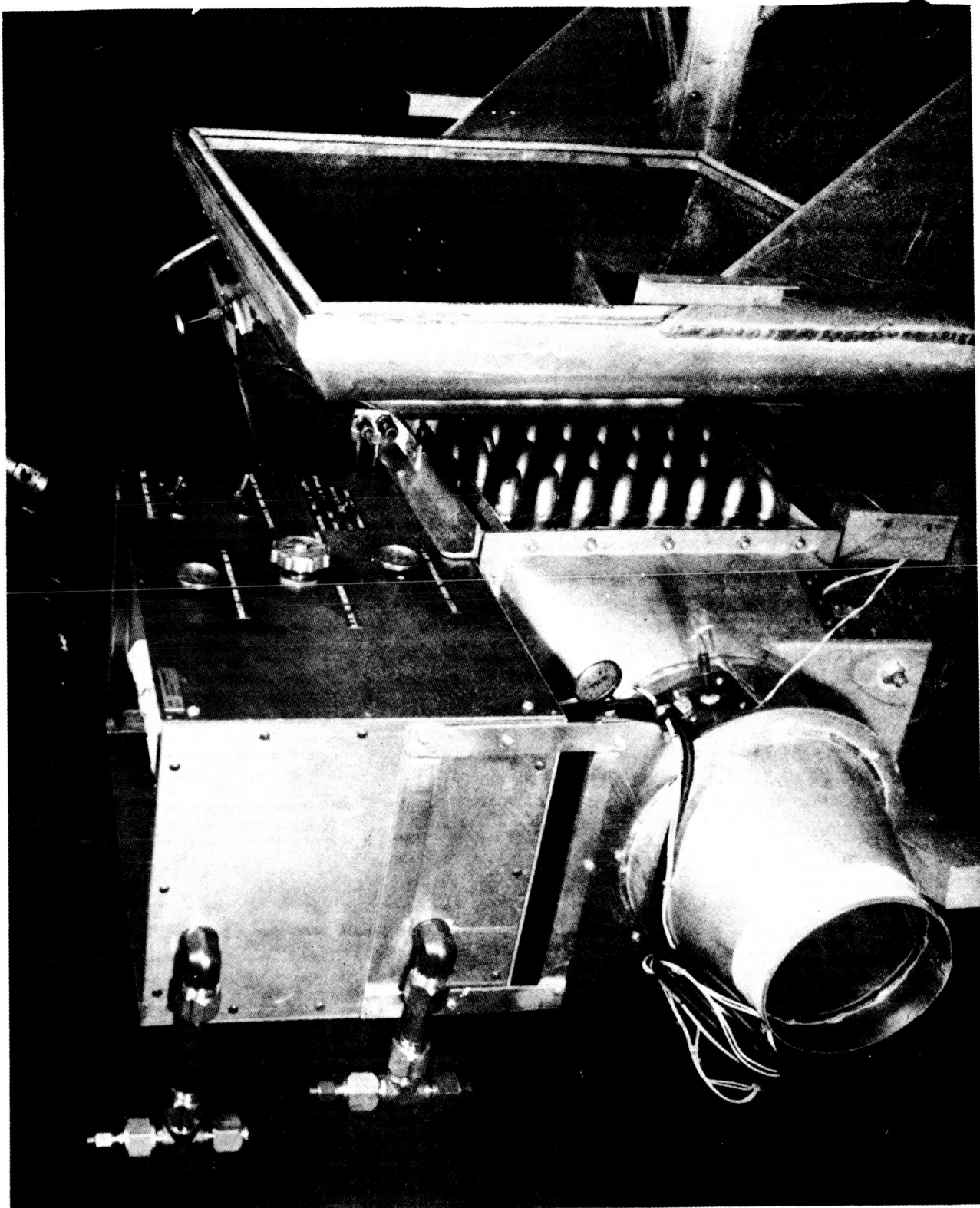


Photo 18: TEMPERATURE AND HUMIDITY CONTROL SYSTEM — MESA II  
Blower Not Shown

6.1.7

## PERSONAL HYGIENE AND SHOWER SYSTEM

6.1.7.1

### MESA I

#### DEVELOPMENT

The basic requirement was to provide a system for maintaining body cleanliness, personal cleanliness and appearances. To meet this requirement the shower system recycled the used shower water for regeneration into usable water. The personal hygiene system transported the dirty water to the waste system for further treatment.

The MESA I shower system design was based on the general concept that two gallons of water could be continually recovered through proper treatment and filtration for reuse and that heated cabin air could be used as a drying medium. In order to accomplish this a shower system was designed that consisted of the following components:

- A. Shower stall with water spray and drying air.
- B. Multi-filtration unit that provided for chemical filtration (charcoal, and ion exchange) of the water, holding tanks, and the necessary pumps and plumbing.

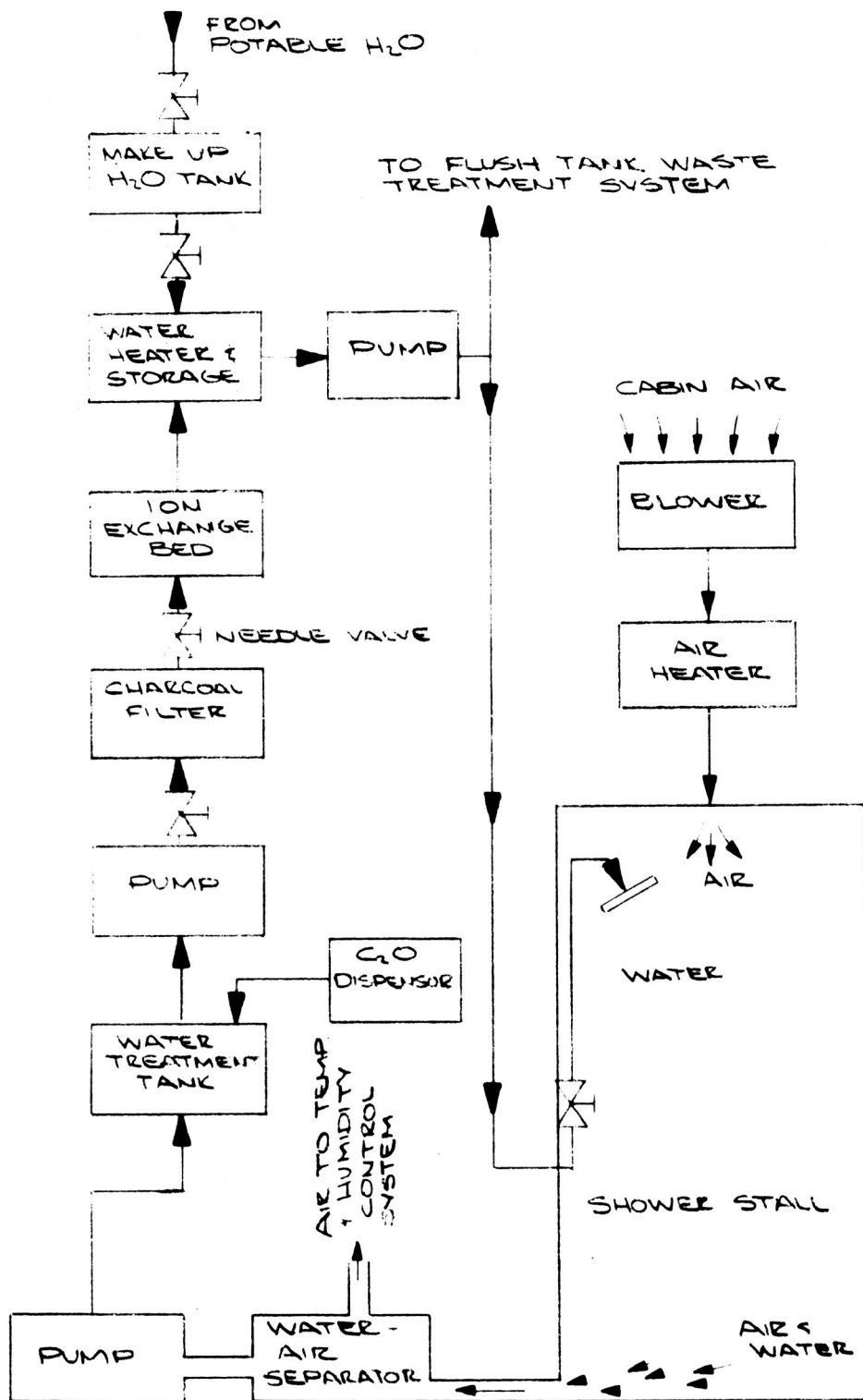
Water from the shower system was used for the toilet flush water, with make up obtained from the water system.

The personal hygiene system consisted of a sink, mirror, lights and electrical power for shaving. A non-spring loaded tap was provided, the water supply was by gravity feed from the water treatment system, the sink was drained by a centrifugal pump and a ball type check valve was installed in the line between the pump and the waste system.

Both systems were tested in the laboratory and operated in a satisfactory manner. The final configuration is shown in block diagram Figure 36 for the shower system and Figure 37 for the hygiene system.

#### SYSTEM TESTS

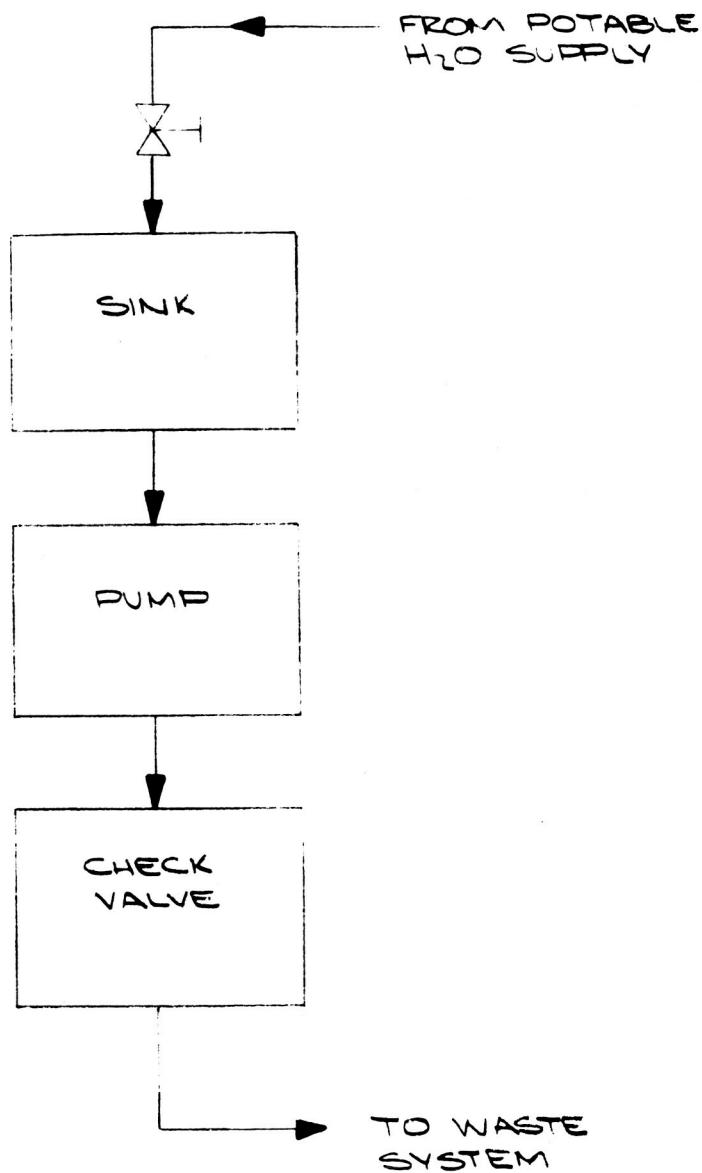
During the two day pre test both systems were used and there were no reported problems with either system. During the  $4\frac{1}{2}$  day abort test both systems were operated. There were no reported problems with the shower system. The personal hygiene system functioned properly with the exception of the check valve in the drain line which continually plugged. Another undesirable feature was the long time required to pump water from the wash bowl to the waste system.



## SHOWER SYSTEM

MESA I

FIG. 36



PERSONAL HYGIENE SYSTEM  
MESA I  
FIG. 37



The personal hygiene and shower system requirements did not change from those of MESA I. The shower system was modified to add an adjustable defuser plate at the air inlet to the shower stall to provide the crew with a means for individual adjustment of the drying-air flow. The personal hygiene system was modified as follows:

- A. The drain line check valve was redesigned using a rubber flap valve housed in a plexiglass cylinder.
- B. A used-water sump was added to the system. A submersible pump controlled by a float-microswitch provided for automatic draining of the system to the waste system. A screen was included to act as a solids trap.
- C. As a means of conserving water the non-spring-loaded faucet was replaced with a spring-loaded faucet.

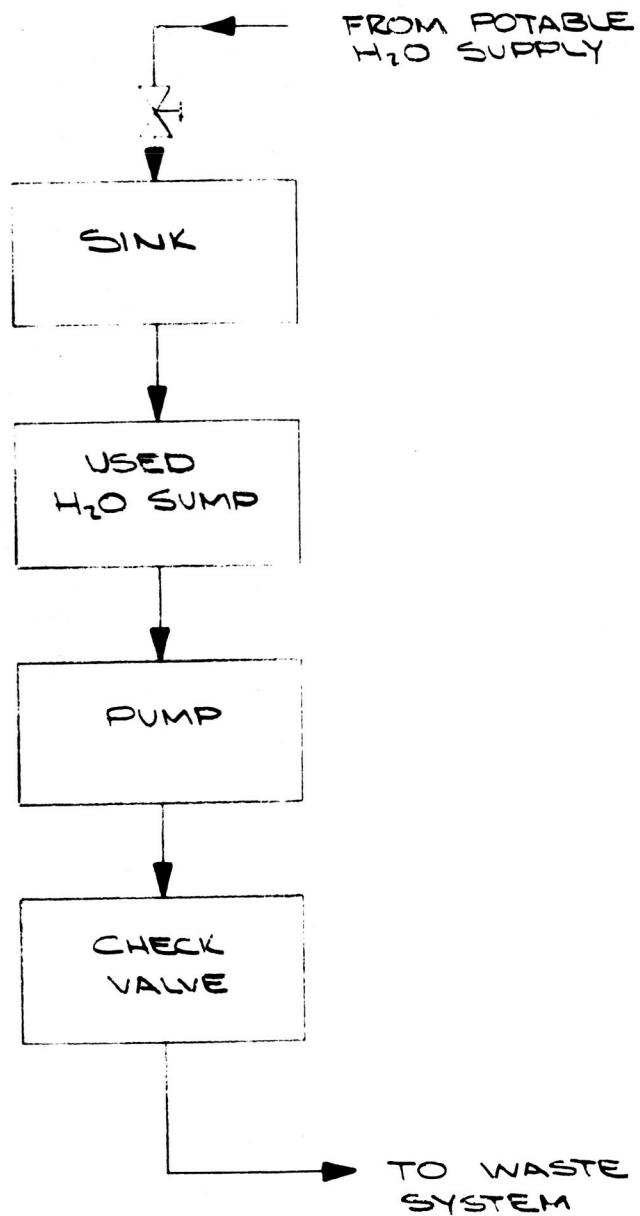
The final configuration of the personal hygiene system is as shown by block diagram Figure 38 and the shower system is as shown by block diagram Figure 39.

#### SYSTEM TESTS

The personal hygiene system performed satisfactorily during the 17-day test. The shower system was used by the test crew during the manned (4-day) portion of the test and the following items were reported:

- A. On the third day of the 4-day manned part of the test the crew reported that an odor of  $H_2S$  was being given off at the fresh water tank. During the time interval prior to the beginning of the 30-day test an investigation into the possible source of  $H_2S$  generation was made. However, the trouble could not be explained and never reoccurred. During this time interval the charcoal was replaced and the ion exchange resin regenerated on the original sodium cycle.
- B. The time interval required to cool the fresh water tank after pasturization exceeded the allowable limit. In order to speed up the cooling rate a glycol loop was added to the tank.

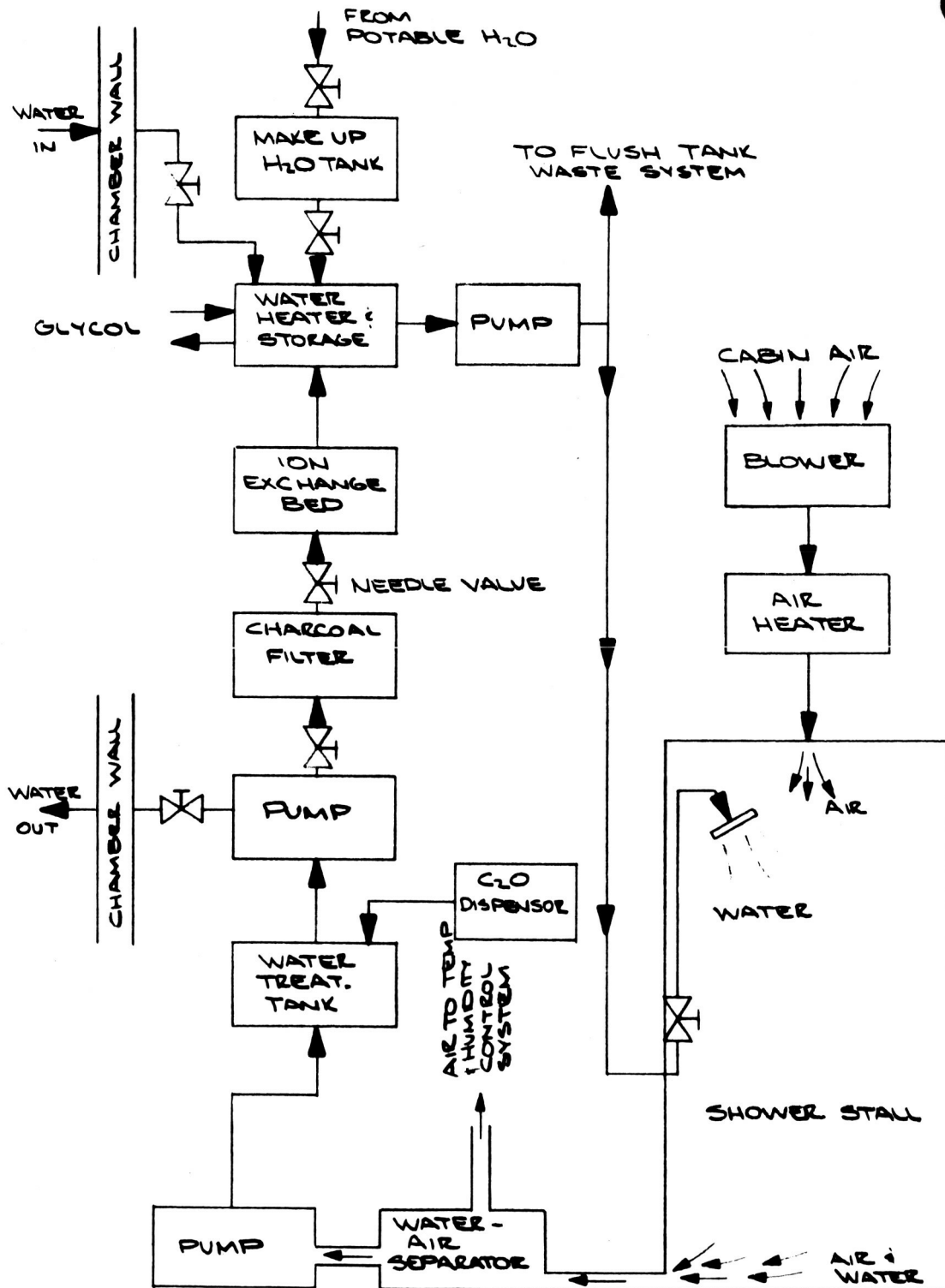
Operation of the Hygiene system during the early part of the thirty day test showed that too much water would become trapped in the bottom of the sump tank and that it became quite rank. The configuration was changed by the crew members to reset the float level and lower the pump inlet to the tank bottom, using an extension of tygon tubing. The screen performed its function



PERSONAL HYGIENE SYSTEM

MESA II

FIG. 38



## SHOWER SYSTEM

MESA II

FIG. 39

very well but was difficult to clean, consequently, it was passed out for cleaning in the lab. Cleaning of tank and screen was done approximately every 5 days

The shower system malfunctioned as follows:

1. Crew reported water would not filter. Investigation showed that the configuration was changed to allow the water leaving the charcoal filter to enter at the top of the ion exchange column. It was also reported that the fresh water was milky. It was recommended that both filters be passed out of the chamber for cleaning. The charcoal was replaced and the ion exchange regenerated. The filters were reinstalled.
- B. Crew reported fresh water tank cooling not uniform. A spare pump was used to modify the configuration to provide circulation of the water in the tank. No further trouble reported.
- C. Again the crew reported the water to be milky and slimy. The slimy feeling was due to high pH. Both filters were again passed out of the chamber. At this time laboratory experiments were performed and it appeared that the addition of more CAO would precipitate the soap on the charcoal. To help mix the CAO thoroughly with the used water a pump was plumbed to the tank to circulate the water. This approach also proved to be ineffective and any further attempts to improve the system were abandoned. The emergency chamber penetrations were used to drain the used water and to supply fresh water.
- D. Crew reported difficulty with transferring the water from the shower drain to the used tank because of loss of prime in the pump. A by-pass line was added to the plumbing which provided easier priming.

#### 6.1.7.3 Recommendations

##### Personal Hygiene System

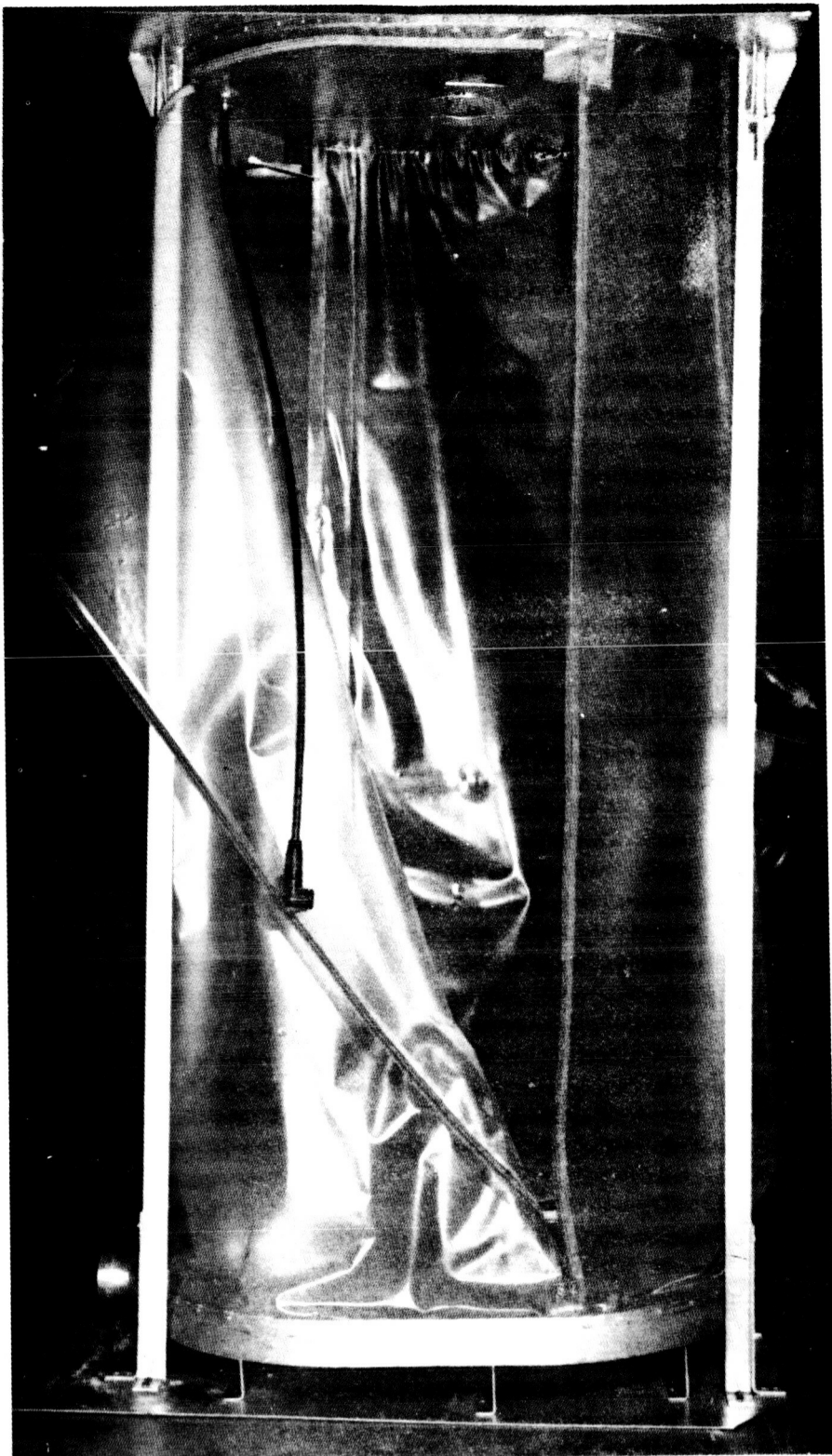
Recommendations are as follows:

- A. Replace plastic impeller pump with a self-priming pump.
- B. Investigate use of paper filters instead of stainless steel screen that could be disposed of in the toilet.
- C. Eliminate sump.

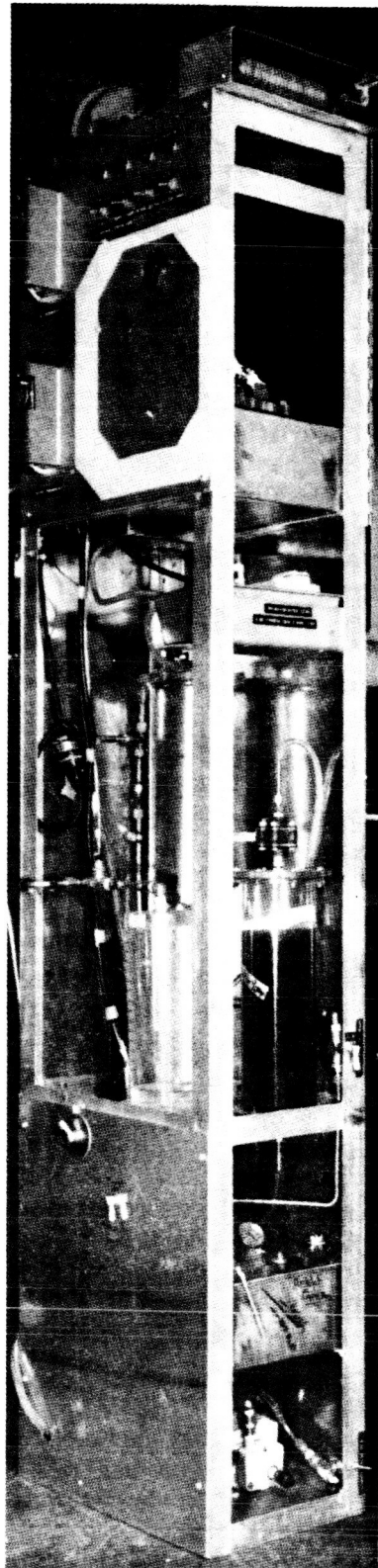
##### Shower System

Recommendations are as follows:

- A. A chemical research program necessary to solve the problem of soap precipitation, and control of pH.
- B. Self-priming pumps should be used.



**Photo 19:** SHOWER STALL SHOWING SPRINKLER HEAD AND TUBING — MESA II



**Photo 20:** SHOWER SYSTEM — FILTERS AND TANKS — MESA II

## 6.1.8 FOOD PREPARATION SYSTEM

### 6.1.8.1 MESA I

#### DEVELOPMENT

The basic requirement was to provide a facility enabling the crew to reconstitute freeze dried food. The detail requirements are as follows:

- A. Provide hot water at a temperature of 90°F and 165°F and cold water at 45°F.
- B. Provide a warming oven capable of maintain temperature at 90°F and 165°F and a cold box at 45°F.

The engineering concept used to meet the requirement was as follows:

- A. A three liter stainless steel tank containing an electric emersion heater thermostatically controlled was used for supplying hot water. A tank of the same size with a braised spiraled glycol tube was used for the cold water supply. Water was fed to both tanks from the potable tank of the water treatment system by gravity.
- B. An insulated metal box partitioned into two parts was used for the warming oven and the cold box. The water tanks were installed inside the box. The left side was equipped with a strip heater and thermostat and the right side contained the glycol cooling coils. Also installed in the box were two manually operated piston and cylinder units with adjustable stops calibrated in ounces for use in metering the water. The cylinders were plumbed through check valves to the nylon dispensing nozzles. Access was provided by two hinged doors.

Following installation in the chamber, calibration tests were made to establish the thermostat settings for the two temperatures required for both the hot water tank and warming oven. A check was also made to verify the temperature of the cold water and box.

The final configuration of the system is shown on block diagram, Figure 40 .

#### SYSTEM TEST

An evaluation of the systems performance was made during the pre MESA I test and the attempted 30 day test. The only reported malfunction was a small leak in the hot water dispensing nozzles.

DEVELOPMENT

After the aborted test the following design refinements were made:

- A. For toxilological reasons the plywood cabinet was replaced with a metal unit.
- B. The door seal material was replaced with a less odorous rubber and the door latches were redesigned to provide more positive latching.
- C. The heater thermostat control knobs for both the oven and tank were mounted on the face of the box for easy access.
- D. Thermometers were added to show the temperature of the water in the tanks and in the boxes.

The configuration for MESA II is as shown on Figure 40 .

SYSTEM TESTS

Prior to the 17 day test, calibrations were made to determine the knob positions for 90° F on the thermostats for both the tank and oven. During the test no additional calibrations were made but it was noted that the cold box temperature was about 5° F higher than the water tank. During the 4 day manned part of the test the crew used only the cold water facilities and reported no malfunctions. Following the 17 day test the oven and hot water thermostat knob positions for 165° F were established.

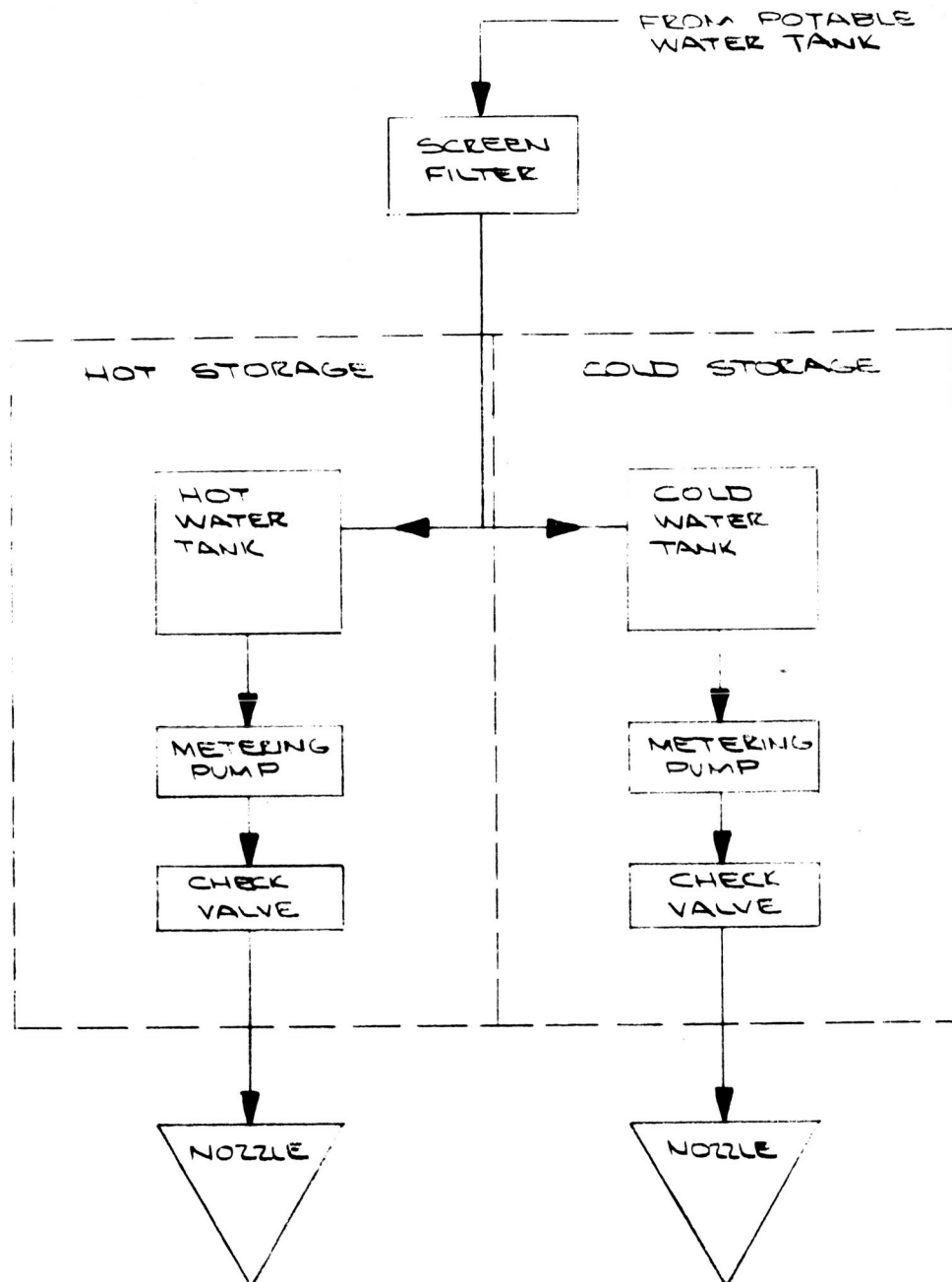
The system performed very well during the 30 day test. Malfunctions and crew criticisms are as follows:

- A. Both water dispensing nozzles leaked caused by improper check valve seating. However, the leak was stopped by rotating the nozzles to the up position.
- B. Crew criticised the need for applying a substantial force to the piston in order to meter water. Tight "O" ring fits and possible swelling of the plastic could account for the high load.

RECOMMENDATIONS

Based upon the satisfactory performance of the system the only recommendations change is to develop a different concept for metering water requiring less actuating force. The leak problem reported could be easily corrected by use of better quality check valves.





FOOD PREPARATION SYSTEM  
MESA I & MESA II  
FIG. 40

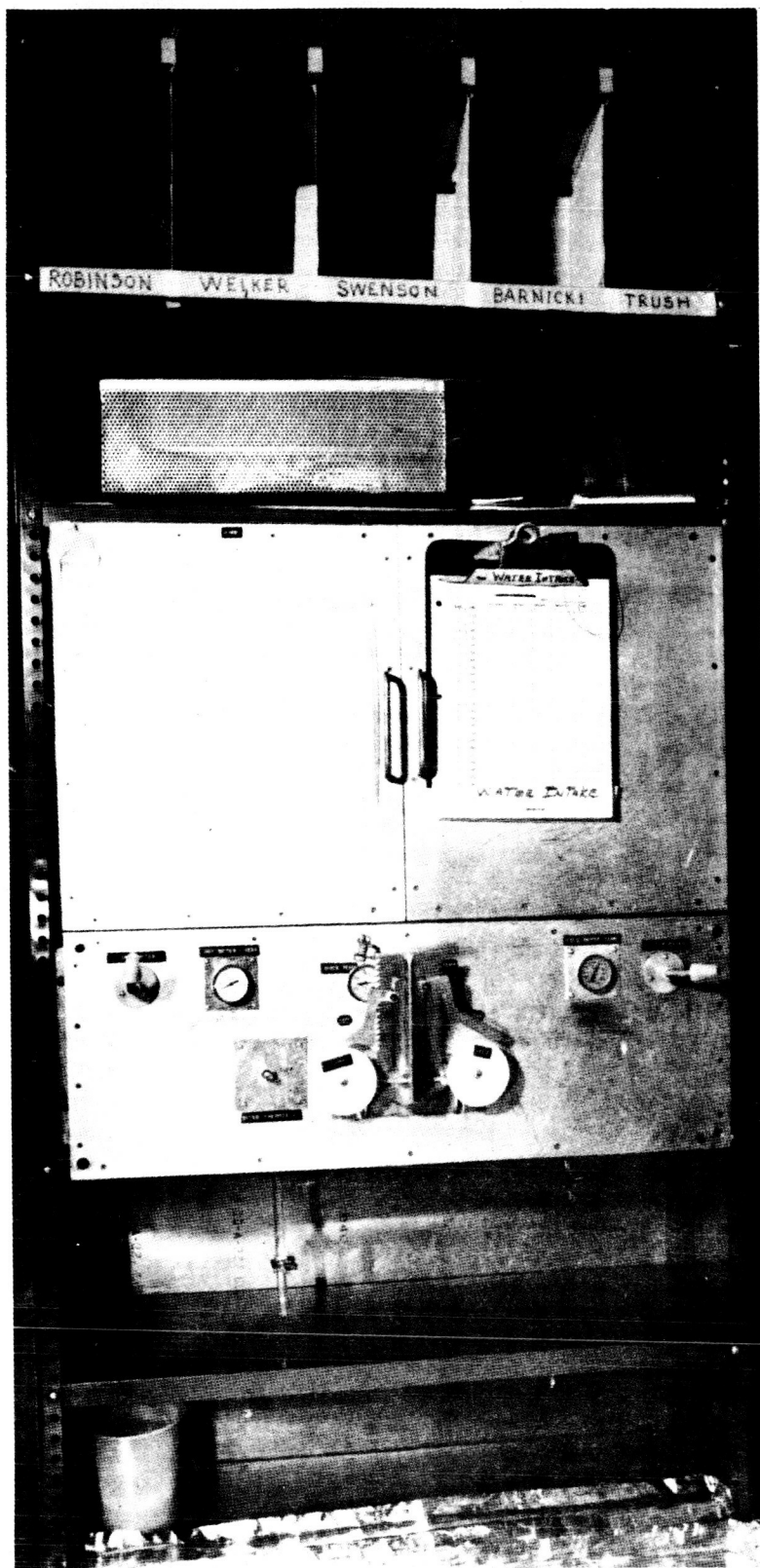


Photo 21: FOOD PREPARATION CABINET AND STORAGE — MESA II

6.1.9 TEST BED

6.1.9.1 MESA I

DEVELOPMENT

The basic requirement was to provide a pressure chamber to contain the life support equipment necessary to maintain life, to provide living accommodations, food and clothing stowage for five people for thirty days and the subjects. In addition, provisions were to be available to allow the passing of samples in and out of the chamber.

The variable pressure chamber used to encapsulate the MESA system was designed and built by the Vacudyne Corporation of Chicago. It consists of a large rectangular vacuum chamber connecting to a smaller cylindrical chamber consisting of an airlock and a pressure section. The vacuum chamber is 22 feet long, 8 feet high, and 10 feet wide with one entire end consisting of a door which slides open to permit entrance of large pieces of equipment for testing. The chamber is also accessible through smaller personnel doors located in the ends of the cylindrical chamber. The cylindrical chamber has an 8-foot diameter and 16-foot overall length. A bulkhead with a personnel door divides the chamber to form two separate compartments. The total chamber volume is 2350 cu. ft.

The cylindrical chamber, in addition to its vacuum capability, may be pressurized to 7 atmospheres. A rapid decompression device is mounted on the top of the chamber connecting the large rectangular section to the cylindrical section.

To permit viewing of the chamber interior, 10 windows are placed in strategic locations.

Approximately 40 penetrations were available to facilitate installation of test components. The penetrations vary in size from 1/2 inch to 6 inches.

To adapt the variable pressure chamber to meet MESA requirements, minor modifications were necessary. The following is a list of modifications and their purpose:

A. Isolation Plugs for Rapid Decompression Device

Prevented possible contamination of chamber atmosphere and eliminated a possible source of air leakage.

B. Removal of Cylindrical Section Interior Door

Permitted greater utilization of interior space for crew sleeping area.

C. Penetrations

Special adaptors were fabricated to facilitate electrical and plumbing installations.

D. Pressure Control

An automatic positive pressure control was designed and fabricated to pressurize and maintain a positive pressure inside the chamber at all times. The control included a meter to record volume of "make-up" gas required during test series.

E. Removal of Unnecessary Equipment

All chamber lighting, valving and air conditioning equipment not needed to support chamber operations during the test was removed from the chamber interior.

F. Sealed Chamber Windows

All of the windows except for one at the living area and one at the operations area were sealed. The windows at the living and operations areas were covered with one-way glass which did not allow the subjects to see out.

G. Air Lock

A 6-inch diameter air lock was installed in the cylindrical section to permit passing in and out small items necessary to conduct the test.

The chamber was divided into three general areas. These were the sleeping area, living area and the operations area.

In addition to the systems mentioned elsewhere in this document, the chamber was furnished with the following equipment:

- A. Bunks
- B. Food storage racks
- C. Clothing stowage lockers
- D. Table and chairs
- E. Command Console

The command console is located in the operations area of the chamber and was manned 24 hours/day. The command console served the following functions:

- A. Provide for central electrical power source for all life support systems.
- B. Provide a central monitoring station for the status of the life systems.
- C. Present a series of performance tasks to the crew members.
- D. Provide a central log-keeping station.
- E. Provide a central station for communication with the outside of the chamber.

The equipment and subsystems were made of plywood for the MESA I tests.

#### SYSTEM TESTS

Chamber leakage testing was conducted on a continuing basis as the test components were being installed. This procedure indicated the effect of each component on chamber integrity and leakage rate. Adjustments were made on the chamber and test components to ensure that the total leakage did not exceed one pound of air per day. All leakage determinations were reduced from the automatic pressure control system readings, and based on the total make-up nitrogen gas requirement for a period of 24 hours or more.

#### 6.1.9.2 MESA II

#### DEVELOPMENT

The basic requirement for MESA II were the same as for MESA I. In addition, it was decided to install a personnel access lock and a large air lock. The chamber configuration for MESA with the following additional modifications. (See Fig. 41 )

##### A. Air Filters

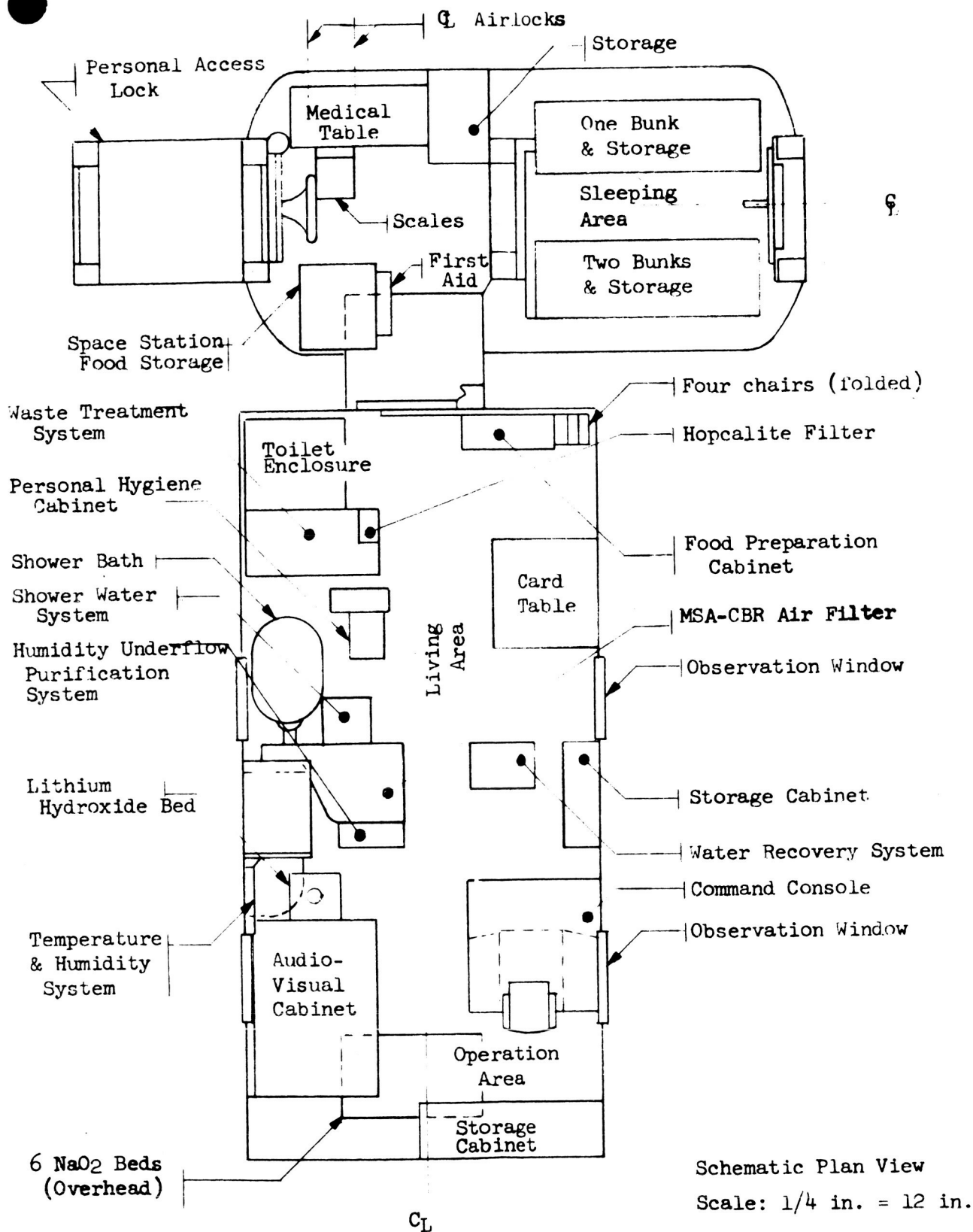
Two MSA CBR filters were attached to the chamber air in-bleed system to permit complete flushing of the chamber air prior to start of tests.

##### B. Air Locks

An additional air lock 10" diameter was installed in the cylindrical section to permit passage in and out of small items necessary to conduct the test series.

##### C. Large Personnel Access Lock.

Permitted access by personnel, during the unmanned portion of the



CHAMBER DETAILS  
MESA II  
Figure 41

test, without disturbing the environment created by test components.

D. Cargo Door Latches

Adjustable link assemblies were designed and fabricated to replace standard "fallaway" type latches. The adjustable links permitted sealing of the cargo door. For internal chamber pressures up to 2 psia.

E. Paint Removal

All paint was sandblasted from the chamber interior to prevent possible contamination.

F. Wood Removal

Prior to the start of the 17-day MESA II test, all of the furnishings and system components made of plywood were reconstructed of metal.

SYSTEM TESTS

Because of the increased noise level in the chamber, due to the loss of the sound deadening capability of the plywood, acoustical tests were conducted in the chamber. A rug made of special non-toxic material was installed on the floor and the air conditioning system was insulated. The noise level in the chamber was at an acceptable level. There was a noticeable improvement in the speech communication environment based on SIL criteria because of the sound absorption provided by the rug. Fig. 42 shows the noise level in the operations and living areas, Fig. 43 shows the noise level in the sleeping area and Fig. 44 shows the noise level in the audio-visual booth.

Leakage tests were conducted in the same manner as for MESA I.

During the 30-day test the total amount of make-up  $N_2$  required was 209 cu. ft. It was calculated that 91 cu. ft. of make-up  $N_2$  was required to maintain the chamber pressure prior to the start-up of the respiratory system. The additional 118 cu. ft. of make-up  $N_2$  was used because of atmospheric pressure changes, leakage through the air locks and accidental venting through the gas sampling equipment and the water collection system vent. The leakage make-up  $N_2$  averaged 3.7 cu. ft. per day. Based on the total chamber volume, the average requirement for make-up  $N_2$  was 0.16% per day.

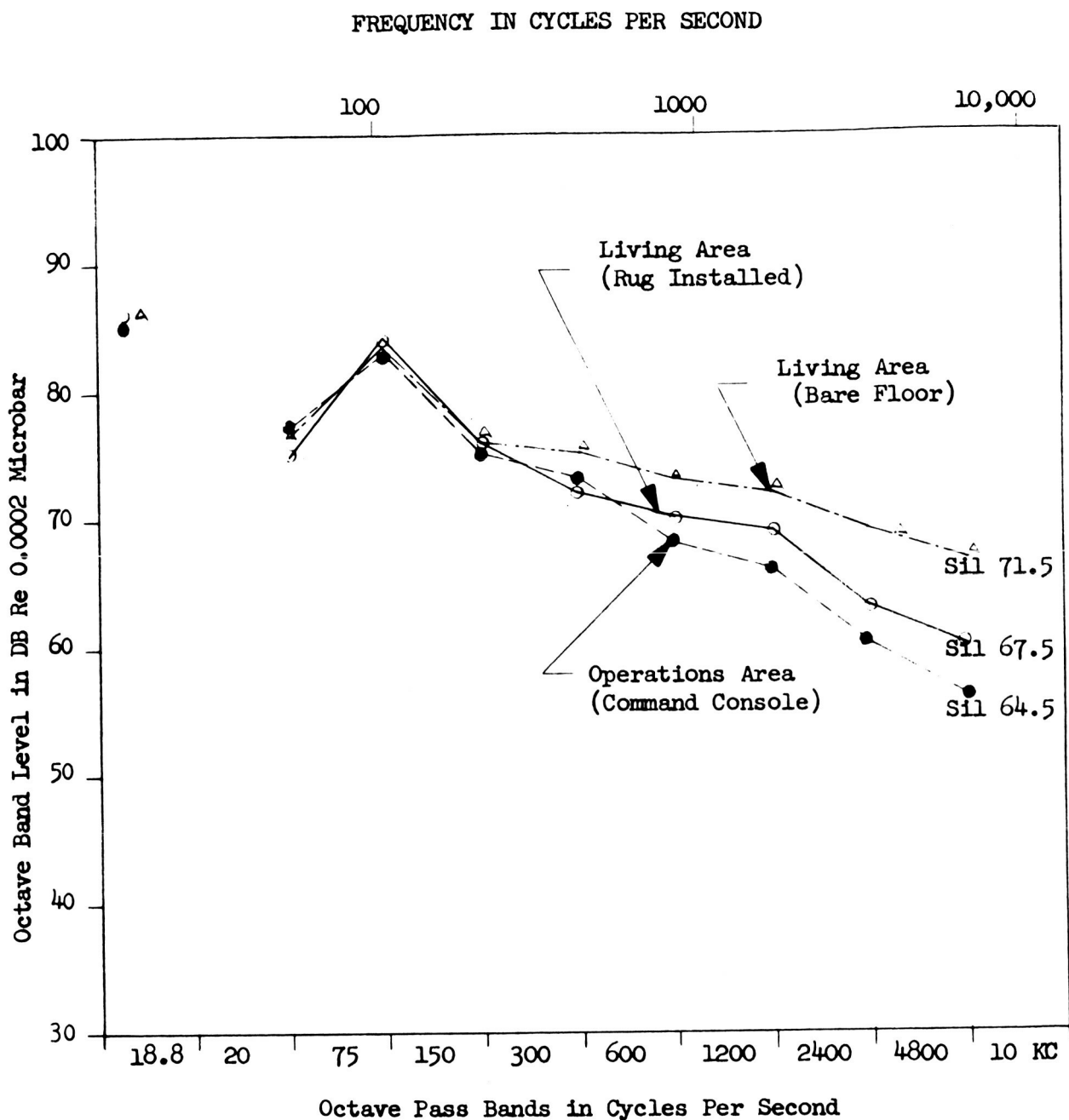
From the data it can be seen that the leakage was very small, that there was a minimum change of the chamber air and the contaminants generated by the systems remained in the chamber.

The chamber provided a satisfactory test bed. The arrangement of the equipment and the space available was such that the functions of work, sleep and "living" could be accomplished with a minimum of interference between the crew members.

The noise level in the cabin was acceptable, but the sleeping area should be isolated from the operations and living areas to a higher degree than they were for the MESA program.

Consideration should also be given to accoustically isolating the chamber from the outside environment. Noise from equipment and personnel located outside the chamber could be heard through the steel walls of the chamber and proved disconcerting to the test crew.

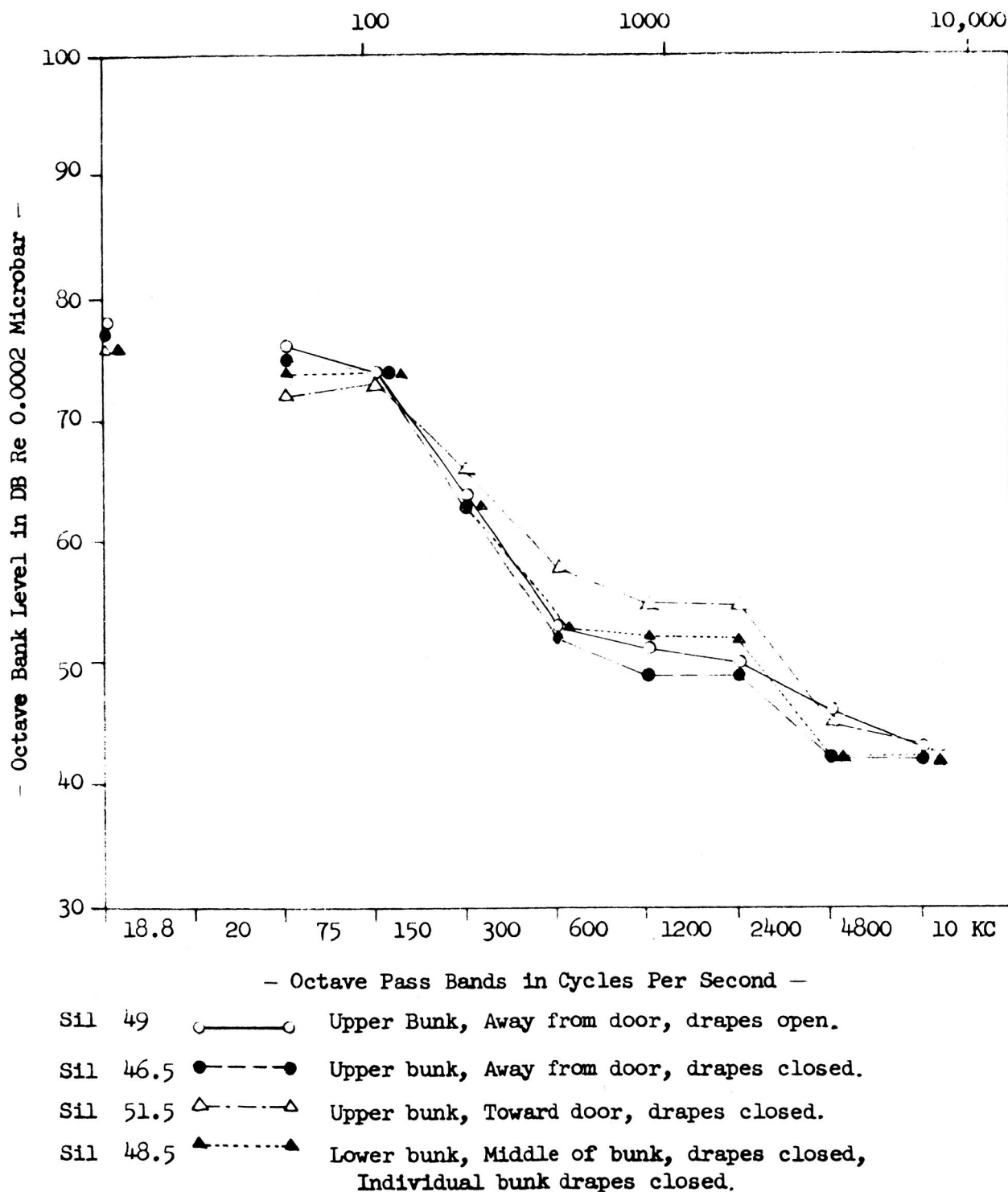




NOISE ENVIRONMENT - LIVING AND OPERATION AREAS

Figure 42

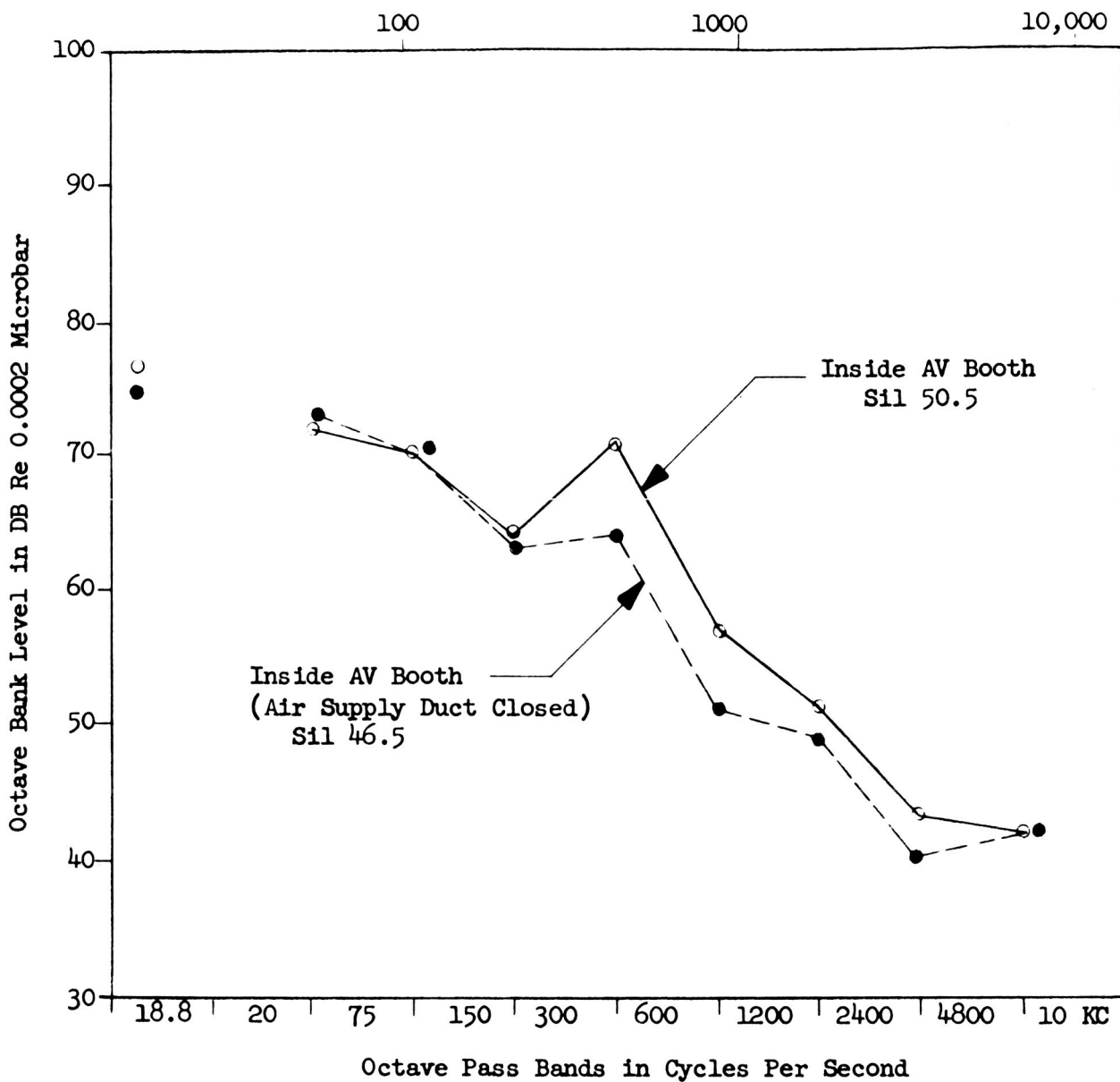
— FREQUENCY IN CYCLES PER SECOND —



NOISE ENVIRONMENT-SLEEPING AREA

Figure 43

# FREQUENCY IN CYCLES PER SECOND



NOISE ENVIRONMENT- AV BOOTH

Figure 44

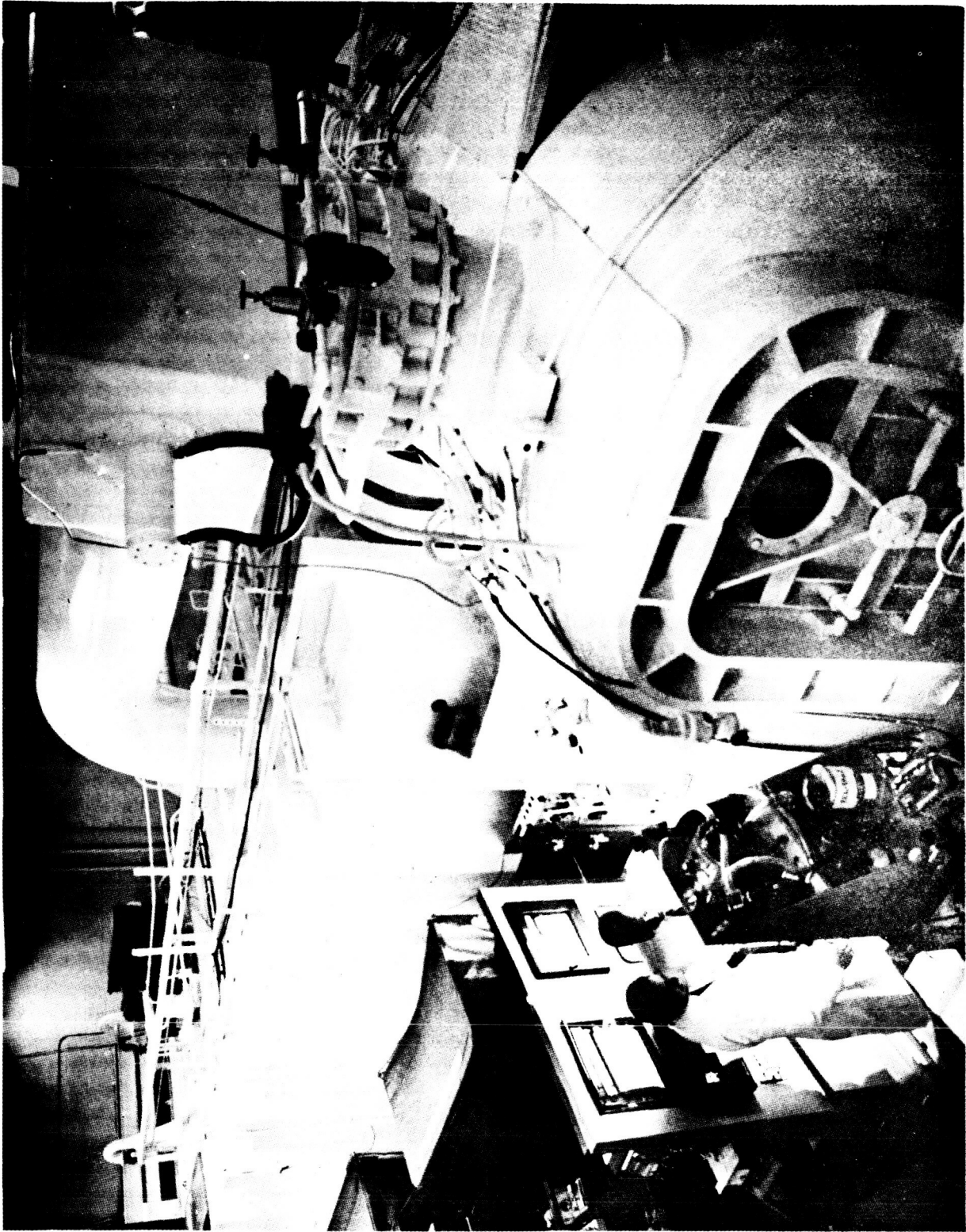


Photo 22: MESA TEST CHAMBER

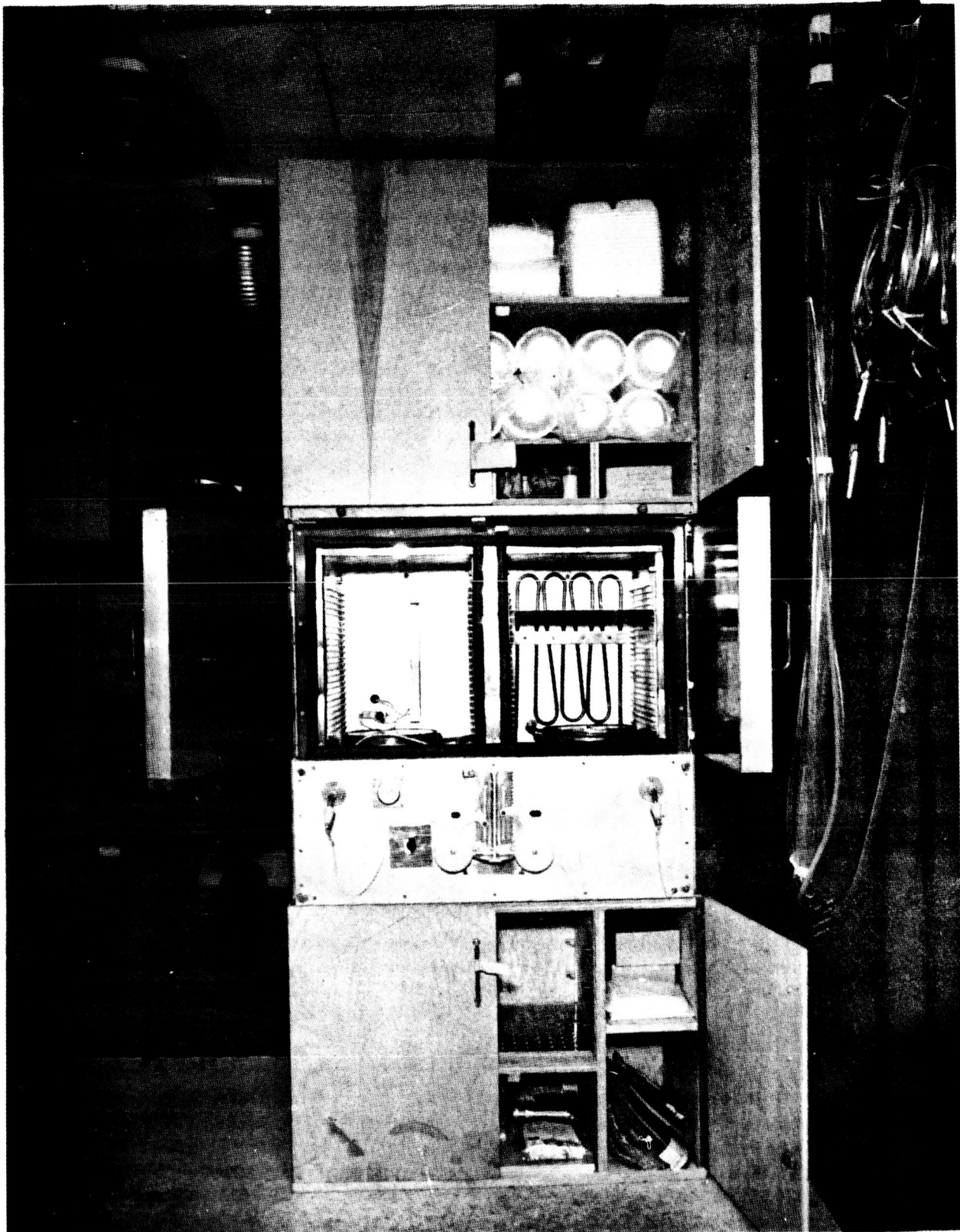


Photo 23: MESA I CHAMBER SHOWING PLYWOOD, CEILING AND FLOOR TILE

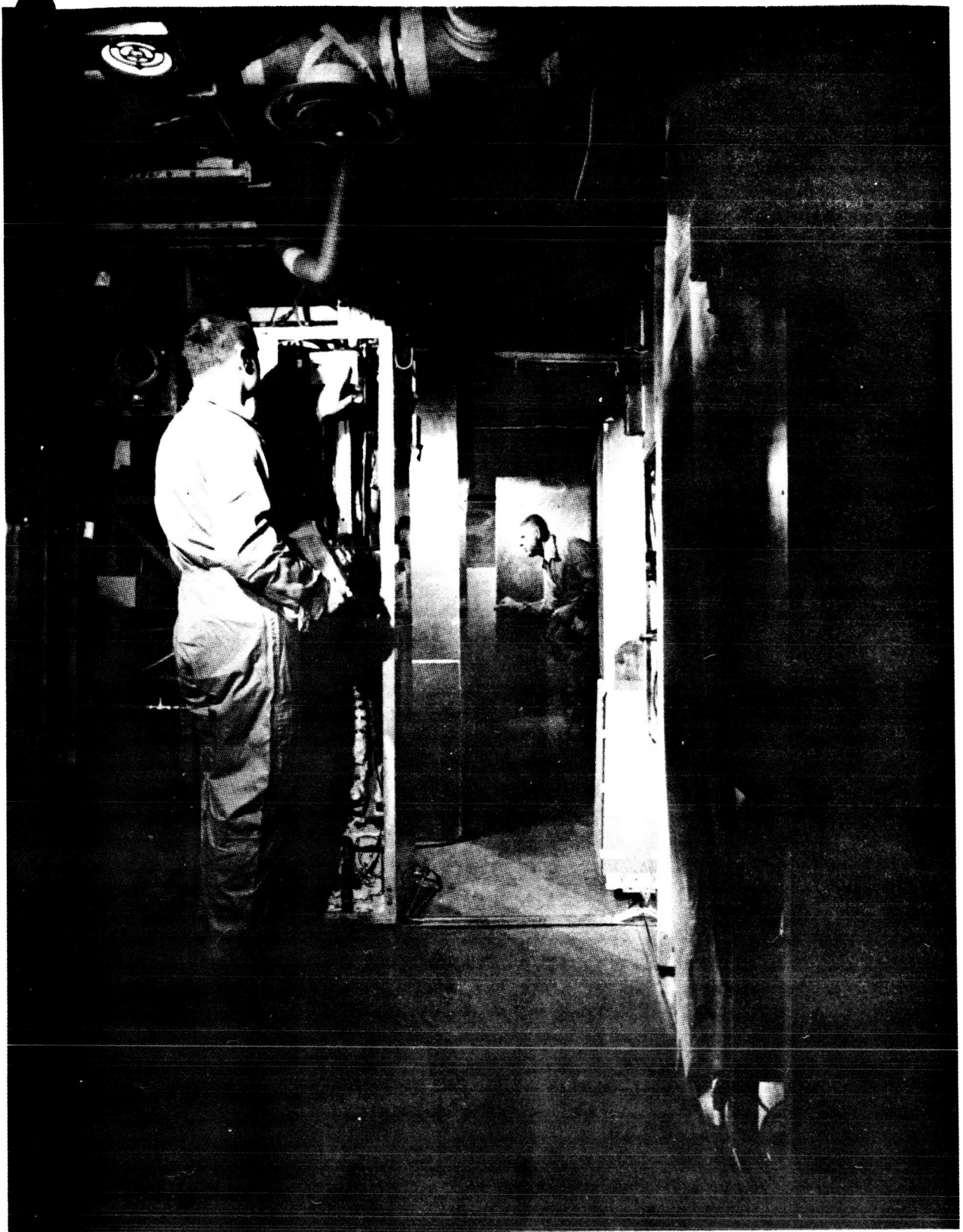


Photo 24: MESA II CHAMBER — MAIN CHAMBER



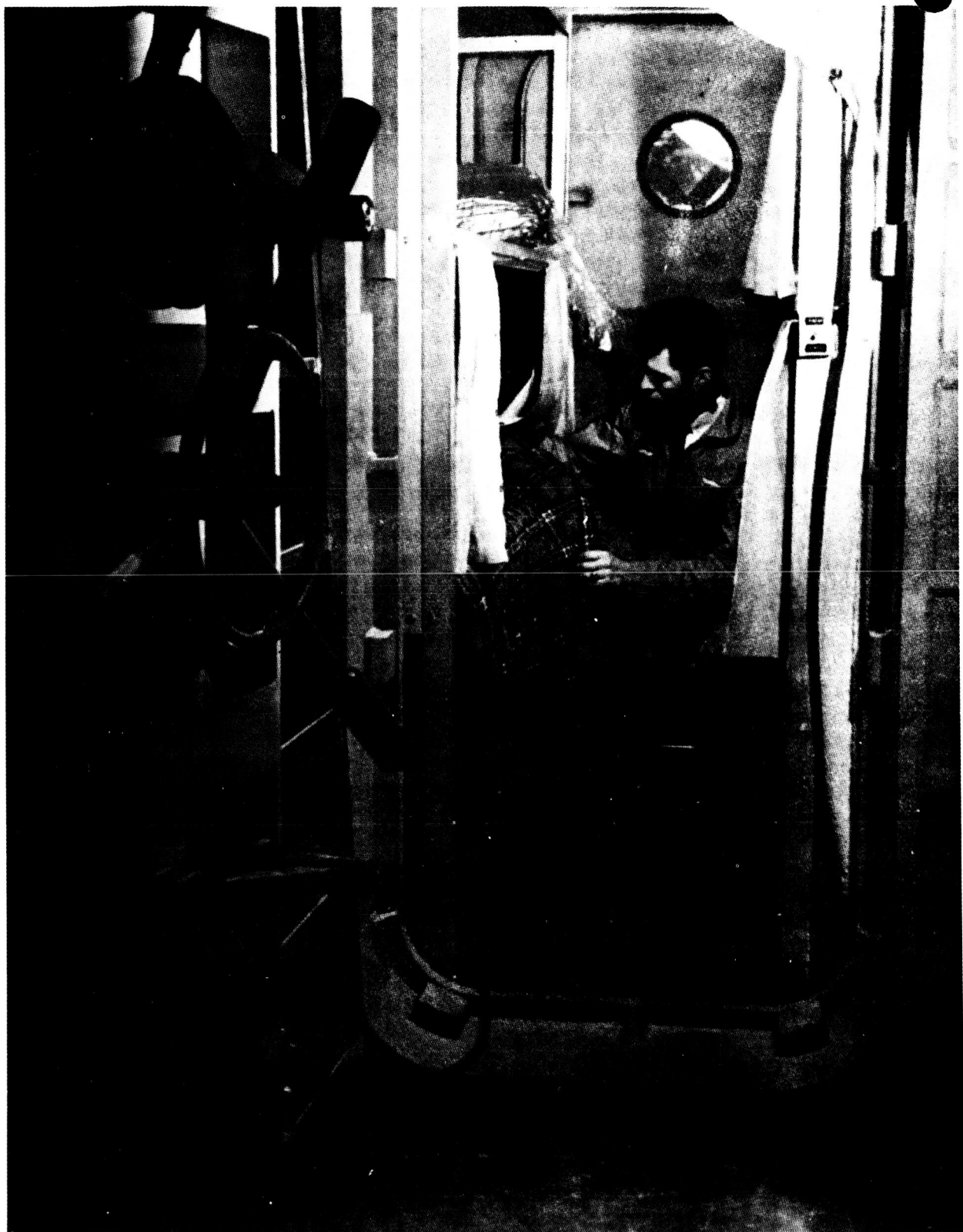


Photo 25: MESA II CHAMBER — SLEEPING AREA

RECOMMENDATIONS FOR A FIVE MAN - 30 DAY SYSTEM

This section contains the results of a review of possible life support subsystems. A recommended 5 man - 30 day life support system is presented along with subsystem selection rational.

A final selection of any life support system without detailed trade studies involving space vehicle design parameters is not possible. But, on the "broad basis" comparison, the selected system has merit, and will be very similar to a final choice if detailed trade studies are conducted.

The recommended 5 man - 30 day life support system consists of:

1. Respiratory Support
  - a. Molecular Sieves (regenerable) for CO<sub>2</sub> control.
  - b. Sabatier Reactor for O<sub>2</sub> regeneration.
  - c. Electrolytic cell for O<sub>2</sub> production.
2. Waste Treatment
  - a. Feces and organic waste collection bag.
  - b. Chemical treatment of collected waste.
  - c. Storage of treated waste.
3. Water Treatment

Vacuum compression - pyrolytic distillation
4. Trace Contaminants Control
  - a. Material Selection
  - b. Catalytic Oxidizer
  - c. Humidity condensate and Chemical Absorber
  - d. Activated charcoal
5. Humidity underflow

Feed to water treatment subsystem
6. Air Conditioning
  - a. Zone coolers for temperature control
  - b. Central, cold plate condenser for humidity control.
7. Personal Hygiene
  - a. Improved MESA shower system
  - b. Mechanical shower
  - c. Chewing gum, mouth wash, and eatable tooth paste for dental care
  - d. Clothes washer



## 8. Feeding

- a. Improved MESA system
- b. Irradiated freeze dried food

### RESPIRATORY SUPPORT

#### Oxygen Supply

- A. Stored
  1. High pressure
  2. Cryogenics
  - \*3. Solid chemicals ( $\text{NaO}_2$ )
- B. Regenerated
  1. Sabatier
  2. Botsch
  3. Solid electrolyte
  4. Molten salts

#### $\text{CO}_2$ Control

- A. Chemical
  - \*1. Chemisorption ( $\text{LiOH}$ )
  - \*2. Solid chemicals ( $\text{NaO}_2$ )
- B. Regenerable
  1. Molecular sieves
  2. Solid amines
  3. Silver oxides
  4. Electro chemical

#### \*MESA

The various methods considered for respiratory support for a 5 man-30 day system are outlined above.

The 150 man-day mission requires that oxygen regeneration be used on a weight, power, and volume basis. This in turn calls for a regenerable carbon dioxide control system to supply the oxygen regeneration system with recovered metabolic carbon dioxide. A third item, an electrolytic cell, is needed if either the Sabatier or Botsch reaction is used for oxygen regeneration.

Based on the mission requirements, power, weight, volume, availability, and an assumed high power penalty, a combination of molecular sieves - Sabatier reactor-electrolytic cell have been selected for future system recommendation.

The proper electrolytic cell has not been determined but will be either membrane, phosphorons pentoxide, or liquid electrolyte.

#### WASTE TREATMENT

1. Chemical Sterilization (gas or liquid)
2. Containment
3. Wet and Dry heat sterilization
4. Incineration
5. Freeze dry
6. Vacuum Dry
7. \*Aerobic Culture
8. Irradiation
9. Freezing
10. Desiccation

#### \*MESA

Waste treatment for a 150 man-day mission requires the handling of approximately 45 pounds of waste material. This can be most efficiently accomplished by a low weight collection and chemical treatment method where power and handling weight penalties are eliminated. It is recommended that a feces and organic garbage collection bag be used with chemical sterilization and subsequent storage of the treated waste.

## WATER TREATMENT

- Pyrolytic distillation
- Vacuum distillation
- Vacuum pyrolysis
- Vacuum Compression - distillation
- Membrane Electrodialysis
- Membrane Permeation
- Freeze distillation
- Ultrafiltration
- Thermoelectric distillation
- Electrolysis fuel cell
- Spray condenser
- Zone Refining
- Wick evaporation

### \*MESA

Above is a list of various techniques proposed for water recovery in a space vehicle life support system.

The recommendation of a water treatment system for a future 5 man 30 day system depends on subsystem development status, power, weight, volume, post and pre-treatment requirements, and the establishment of the final water product potability. Based on the above comparison, it is recommended that a vacuum compression pyrolytic distillation combination unit be used. This would combine the feature of absolute potability afforded by catalytic pyrolysis and low operating cost in terms of power weight and volume.

The MESA system provided potable water, but the high temperature operation (225 F boiler temperature) induced three problems solved by the recommended system: (a) scaling (b) foaming, (c) high carry over of salts requiring ion exchange post treatment.

## TRACE CONTAMINANT CONTROL

- \*Material selection
- \*Catalytic oxidation
- \*Sorption
  - Adsorption
  - Absorption

### \*MESA

Trace contaminant control methods employed in the MESA program are outlined above. The MESA program evidences a requirement for a combination of all the listed methods, therefore, the recommended 5 man-30 day contaminant control system will contain: material selection criteria; catalytic oxidizer; humidity condensate absorber; activated charcoal; and chemical absorbers.

### HUMIDITY UNDERFLOW

- \*Ion exchange
- \*Charcoal filter
- \*Silver Filter
- U.V. Lamp

#### \*MESA

Humidity condensate treatment methods are listed above. The MESA program results indicate that present methods of humidity underflow treatment requires a large penalty in stored supply for charcoal filters. It is recommended that a future 5 man-30 day system include the humidity underflow water in the feed of the waste water treatment system. The quantity of humidity water available suggests that it be used as flush water if applicable

### AIR CONDITIONING

#### Temperature Control

1. Zone cooling
- \*2. Central cooling

#### Humidity Control

1. Adsorption
- \*2. Condenser

#### \*MESA

The MESA air conditioner consisted of a central cooler-condenser with air distribution ducts to distribute the conditioned air.

A recommended system for a future 5 man-30 day system would consist of: 1) Zone coolers without subsequent condensation for temperature control; 2) a small central humidity condenser water removal unit for humidity control.

This approach will have the advantage of lower power requirements with more accurate control of temperatures in various locations in the vehicle.

## PERSONAL HYGIENE

### Body Wash

#### \*Shower

Chemical cleaning pads

### Shaving, Nail clipping, etc.

#### \*Mechanical

Chemical (depilatory salves)

### Dental Care

#### \*Gum

#### \*Mouth wash

#### \*Tooth paste

### Clothing

#### \*Washable

Disposable

### \*MESA

Various methods of providing personal hygiene are listed above.

The desirability of providing a shower in a 5 man-30 day system was established during the MESA program. Although a cleaning pad method for body cleaning can be shown less expensive in trade studies, the development of a low-cost shower system is still recommended.

The mechanical shaving method has proven to be acceptable and is recommended.

Dental care should combine those elements used in MESA (chewing gum, mouth wash, and eatable tooth paste).

A suitable wash sub-system is recommended to maintain the clothing over the selection of disposable clothing.

In general, the metal and physical well being of the crew has dictated system selection versus weight, power, or volume criteria.

## 6.2 TECHNOLOGY

### 6.2.1 TOXICOLOGY

#### 6.2.1.1 MESA I

### DEVELOPMENT

#### A. Basic Requirements

Since contaminants in the chamber atmosphere will occur, provision must be made to predict and determine them, to measure their concentration and to evaluate the physiological response to them.

##### 1. Requirements for list of possible toxic contaminants:

To safeguard the health of test subjects the toxic gases which might occur must be known and limits set for safe operation in their environment.

##### 2. Requirement for toxicology monitoring equipment

The trace contaminants must be detected and their concentrations monitored at levels less than their maximum allowable concentration. Only by constant measurement can harmful evolution be revealed and unsafe conditions found in time to correct them. For most toxic contaminants the detection instruments will have to be sensitive to concentrations in the parts per million range.

##### 3. Requirement for toxic gas sampling:

Representative samples must be taken from many locations in the chamber in a minimum length of time. The samples cannot be altered between the sampling point and the indicating instrument.

#### B. Toxicology Concepts in MESA I

##### 1. Pre-July Studies of Possible Toxicants

In the early phases of MESA concepts trace contaminants were considered as a potential problem area. A literature search was made to determine the most likely trace contaminants which might occur during extended confinement. A list of these compounds was compiled primarily from the work of the following authorities plus Boeing work on the toxicology resulting from thermal degradation of materials for use in space cabins:

H. W. Hays, Advisory Center on Toxicology, Nat'l  
Academy of Science  
H. C. McKee, et. al. Southwest Research Institute  
R. A. Saunders, Physical Chemistry Branch, Navy  
Res. Lab.

TABLE 2  
ATMOSPHERIC GASES AND TRACE CONTAMINANTS

<u>No.</u>	<u>Gas</u>	<u>Atmospheric Gas Monitor</u>	<u>Freeze Out and Absorption</u>	<u>Mast Ozone Analyzer</u>	<u>MAC PPM</u>
1	Oxygen	X			
2	Nitrogen	X			
3	Carbon Dioxide	X	X		10,000
4	Carbon Monoxide	X			10
5	Hydrogen	X			4,000
6	Methane	X	X		5,000
7	Ammonia	X			10
8	Water Vapor	X	X		
9	Methanol	X	X		10
10	Ethanol	X	X		250
11	Propanol	X	X		100
12	Formaldehyde	X	X		0.5
13	Acetaldehyde	X	X		20
14	Acetone	X	X		100
15	Benzene	X	X		5
16	Toluene	X	X		50
17	Hydrogen Sulfide	X	X		2
18	Acetylene	X	X		2,000
19	Nitrogen Dioxide			X	0.5
20	Ozone			X	0.05

T. A. Weber, currently Beckman Instr, Previously  
School of Aerospace Med.

The list of gases included those found in submarine studies, Mercury Space Flights, and simulated space chamber experiments. Gases known to have occurred from isolated sources, which were not **included**, were eliminated from the list. The remaining most likely gases were listed together with arbitrary safe MAC's for a thirty day continuous exposure. The limits were recommended by Dr. Hays or were arbitrarily set at 10% of the industrial MAC for 8 hour exposure. These levels were considered safe under all circumstances. See attached list.

## 2. MESA I Instrumentation Concept

Continuous analysis for a large number of varied types of compounds was required. The instrumentation had to measure major gas constituents in per cent amounts as well as trace gases, in parts per million. The gas chromatograph was the only type of instrument currently available which would handle the varied complex mixtures without computer readout. However, to get the sensitivity required, an ionization detector was necessary. Most ionization detectors were limited to a few classes of compounds, but a newly developed detector by Karmen depended upon ionization in the glow discharge region and could respond to all types of gases including fixed gases, organic vapors, halogenated compounds and sulphur containing compounds. The table of probable trace contaminants shows that the Karmen detector could see all of these gases that can be eluted from columns. Such an instrument had been miniaturized and delivered to NASA, which filled the need for a system which could be made flight ready. A process model gas chromatograph was ordered from Beckman Instruments to have the Karmen detector and an automatic stream selector which could sample a number of stations automatically and in sequence. To separate both permanent gases and organic vapors, a two column instrument was selected with an automatic programmer to switch flow and inject samples.

To back up this instrument's oxygen and carbon dioxide read-out, a continuous monitor was required. A Beckman model F-3 was chosen with its continuous oxygen recording feature. Carbon dioxide is most reproducibly analyzed with non-dispersive infra red instruments so both a Beckman model 15A and an MSA Lyra 300 were selected for the test.

Iodometric detection of the oxidizing gases, ozone and nitrogen dioxide, was read continuously on the Mast Ozone Meter.



Other gas detection methods which were considered as back up for the gas chromatograph were based on chemical color methods. Nitrogen dioxide, ammonia and ozone were to be analyzed colorimetrically. As a ready check for a variety of specific gases chemical detector tubes by MSA and Kittigawa were stocked for emergency and back up usage.

### 3. Concept of Toxic Gas Sampling

Samples should be taken in each critical area. Good circulation is required to give a truly representative sample of the entire quantity of gas. The sampling lines should be flexible essentially inert to the gases, of minimum length, and of sufficient diameter to allow the flow required to give an up to the minute sample. Quarter inch neoprene tubing was selected because it is smooth, flexible, leak proof, and large enough to allow flows of several hundred milliliters per minute without great pressure drop.

Three analytical methods were serviced by the sampling lines - direct gas analysis instruments, concentration sampling traps, and microbiological.

The location of the sampling points were selected to provide information about the toxic gas formation occurring in critical locations and equipment in the chamber. The following table describes the sampling points and the reason for monitoring.

Fig. 45 shows the location and sequence of these sampling points.

Less than detectable concentrations of trace contaminants could build up and become apparent in long or duration tests. To improve the possibility of detection, concentration techniques were developed to collect the contaminants from large volumes of chamber air by freeze out in liquid nitrogen or by absorption on activated charcoal or silica gel. These samples could later be processed by sensitive gas chromatography, chemical or spectrophotometric techniques.

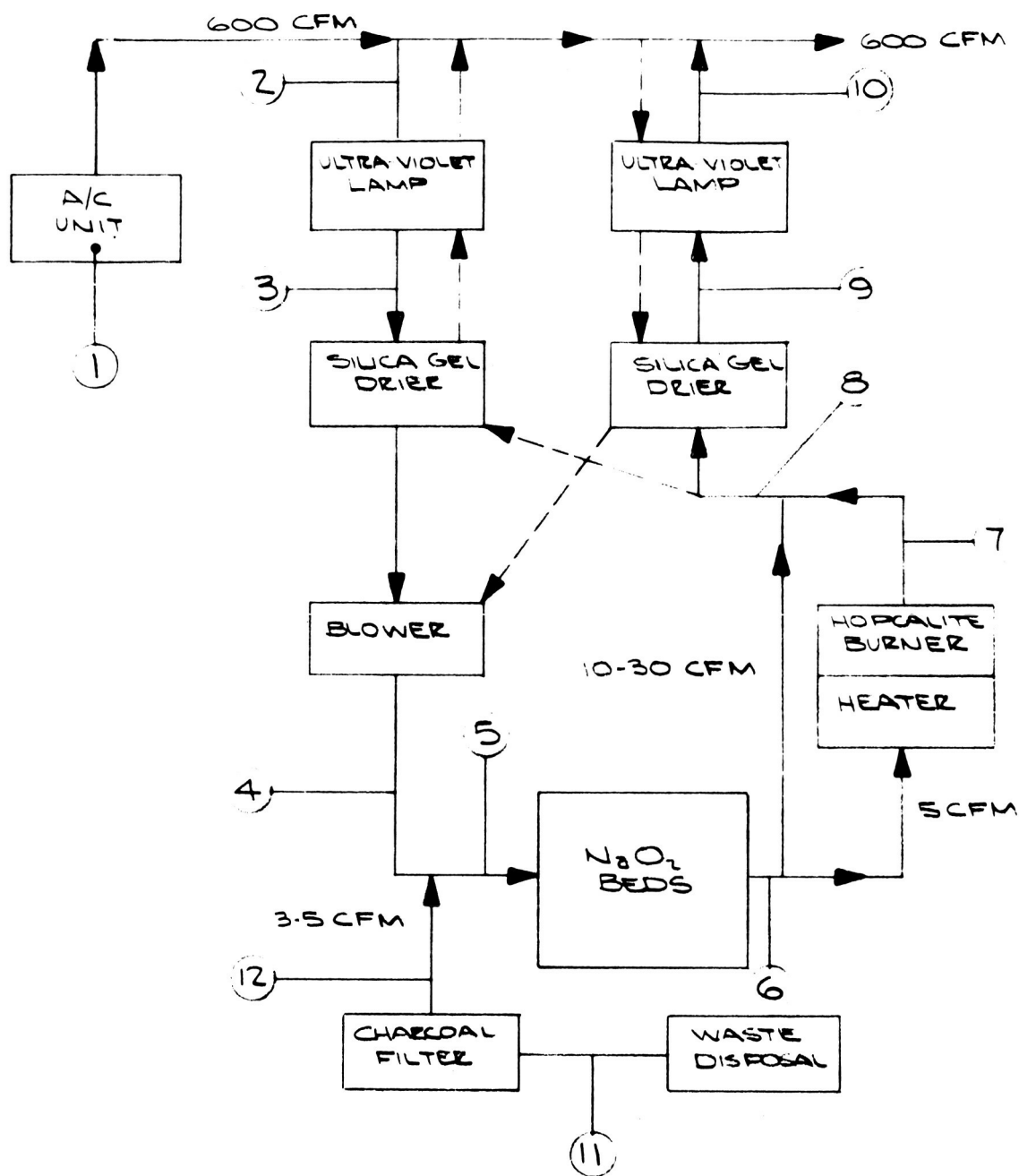
### C. Toxicology Studies

1. In early experimentation with sealed chamber experiments, little in the way of toxicology problems occurred. Plastics sealers, and paints containing volatiles had been avoided. Volatile chemicals were not used. Combustion of materials was generally omitted. However, the combination of many subsystems had not been attempted. Upon integration of the sub-systems for project MESA, problems arose.

For example, in the atmospheric regeneration system, the heat resistant gaskets, filters and tubing which were

## LOCATION OF SAMPLING POINTS

<u>Area</u>	<u>Location</u>	<u>Reason</u>
Main Air Flow	Airconditioner Duct	Best representative sample of chamber air
U-V Lamp	Before and After	Detect production of ozone, Sterilization effect
Silica Gel	Before and After	Check for contaminant re- moval. Check for humidity control.
Sodium Superoxide	Before and After	Determine carbon dioxide- oxygen exchange rate  Check for removal of contaminants.  Measure effect on micro- organisms
Hopcalite Burner	Before and After	Determine contaminants re- moved or generated.
Waste Reactor	Before and After the charcoal filter in the exhaust air line	Check for contribution of trace gases. Determine the release of micro organisms. Check the effect of the charcoal filter for re- moving contaminants.
Other Chamber Areas		Check for stagnation of stratification problems.



GAS SAMPLING DIAGRAM  
MESA I

FIG. 45

required for combining the components did show degradation and gas production upon use at elevated temperatures. "Heat resistant" materials were not resistant enough. Vinylite sleeving for electrical connections gave off odors. The water treatment system produced obnoxious if not toxic vapors. The waste treatment system produced some odors even when operating aerobically. All of these sources gave off obnoxious odors of unknown toxicity. However, it was felt that contaminant removal equipment would control these gases.

2. a. The Karmen detector gas chromatograph was set up with columns and tested for several days before the manned tests began. Sample gases and gas mixtures were injected by syringe. Good separation and qualitative identification could be made with each of the following gases, in the noted volumes, which correspond to 140 ppm:

<u>Compound</u>	<u>Quantity</u>	<u>Retention Time</u>	<u>Attenuation</u>	<u>Peak Height</u>
Cyclohexane	10	5.7 min	$50 \times 10^2$	10
Ether	7.4	2.0	"	13
Formaldehyde	10	10	"	8
Acetone	5.0	3.5	"	7
Ethanol	5.5	8.5	"	5
Water	6	12.3	"	80
CO <sub>2</sub>	(300 ppm)	1.6	"	38

The standard gas mixture gave the following factors for the constituents on an attenuation of  $20 \times 10^2$ .

Gas	H <sub>2</sub>	CH <sub>4</sub>	CO	NH <sub>3</sub>
PPM/div	42	5	12	20

The quantities of organic vapors being used for calibration were not representative of the ultimate sensitivity; however, the instrument was only being used at its mid-range in attenuation. This showed that greater sensitivity was available.

Most of the samples were injected by syringe and the automatic sampling system was tested primarily with the start of chamber testing.

b. All other instruments were calibrated by zeroing, setting the span and checking with knowns. All appeared to be operating normally.

### SYSTEM TESTS

During pre-test of the integrated system, 5 men were in the chamber for two days. Toxicological problems were minor. The carbon monoxide concentration remained about 15 ppm for most of the test. Hydrogen was evolved in the superoxide bed and increased gradually to 2800 ppm by the end of the test. Oxygen was maintained between 19.6 and 21.7%, while carbon dioxide was held below 1.6%. Ammonia was detected in the chamber air in two instances. Gas analysis data did not show that any other unusual gases were present.

When insulation on the Hopcalite catalytic oxidizer overheated, the gases which were evolved irritated the eyes and caused headache and nausea. The symptoms cleared up after the problem was solved.

The test was started without a continuous record of chamber air composition. The continuous recording oxygen and carbon dioxide analyzers followed the programmed sequence of stations with the gas chromatograph, which monitored the chamber air once each four hours. To keep better aware of gross chamber conditions, the two major gas analyzers were given a separate sampling line direct to the chamber, which would give a continuous record of chamber conditions at all times. The carbon dioxide readings on the gas chromatograph did not correspond to the continuous reading instruments when reading the same sample gas. Further investigation would be required to determine the reason. Samples collected with cold traps in liquid nitrogen were transferred to the Wilkins gas chromatograph and detected by the hydrogen flame detector. The known peaks which were separated were attributed to air and water.

During the attempted 30 day test, the chamber gases were monitored with the following instruments:

<u>Gas</u>	<u>Location</u>	<u>Instrument</u>
CO <sub>2</sub>	Chamber	Non Dispensive IR - Beckman 15A
CO <sub>2</sub>	Subsystems	Non Dispensive IR - Lyra 300
O <sub>2</sub>	Chamber	Paramagnetic Sensor - Beckman Model F-3
O <sub>2</sub>	Chamber	Polarographic Sensor - Beckman Model F-3
O <sub>2</sub>	Subsystems	Paramagnetic Sensor - Beckman Model D-2
H <sub>2</sub> , CO <sub>2</sub> , CO, CH <sub>4</sub> , NH <sub>3</sub> , H <sub>2</sub> O, Organics	Subsystems	Karman Gas Chromatograph - Beckman
NO <sub>2</sub> , O <sub>3</sub>	Chamber	Mast Ozone Meter, Kittigawa and MSA Detector Tubes

The gas chromatograph gave good separations and semi-quantitative data. Unknown peaks appeared when high sensitivity was used with the partition column. These peaks were attributed to attack on the column or pressure patterns due to valving. Carbon dioxide and moisture readings with the gas chromatograph still did not correspond to those from other indications; further investigation was required. Otherwise, no unknown gases were seen with the gas chromatograph. The oxygen and carbon dioxide instruments performed well, the mast ozone meter malfunctioned and did not give usable data during the test.

The sampling locations were primarily the same as those for the pre-test and the same sampling diagram applied, Figure 45.

Samples were absorbed on activated charcoal and were frozen out with liquid nitrogen traps. The samples were trapped from the most critical areas for every 24 hour period. The hydrogen flame gas chromatograph was used to analyze the desorbed gases from the traps. The eluted peaks appeared to be primarily air-carbon dioxide, water and  $N_2O$ . Other components were present in insufficient quantities to be identified.

The chamber air became quite rank before the experiment terminated, however unusual gases were not detected with the monitoring instrumentation. The hydrogen concentration increased throughout the experiment, reading a maximum of 1440 ppm in the chamber air near the end. Concurrently, a laboratory test was made using sodium superoxide in contact with aluminum; the hydrogen generation did level off after several days time. The carbon monoxide level in the chamber was held to 5 ppm or less. Traces of ammonia were seen with the gas chromatograph in various systems, but was zero concentration at the end of the experiment. Ozone was detected at a concentration of .087 ppm once during the experiment. Soon after the termination of the test, detector tubes found 0.2 ppm  $NO_2$ , no ammonia, and a positive test of 4 units with a Davis #11 tube which is sensitive to many organic compounds. The organic contaminant was not identified by this test.

Final calibrations of the Karmen Gas Chromatograph showed the following factors for a known mixture of gases at an attenuation of 5,000:

Gas	Conc.(ppm.)	Reading (div.)	Factor(ppm/div.)
Methane	100	27	3.7
Hydrogen	100	6	16.7
Carbon Monoxide	50	6	8.3

Organic vapors showed the following sensitivity at final calibration:

Compound	Sample	Retention	Peak Height	Attenuation
111 trichloroethylene	5 $\mu$ 1	6.7	-36	5000
methyl chloride	5	5.8	-66	5000
methanol	5	7.7	0	5000
ethanol	5	15.2	-25	5000
ethanol	10	10.6	17.5	5000
acetone	5	2.9	3.9	5000
cyclohexane	5	4.8	2.7	5000
ethylene dichloride	5	13.3	-13.0	5000
ethylene dichloride	10	13.3	-130	5000
formaldehyde	5	2.2	1.6	5000
propionaldehyde	5	3.3	2.4	5000

Compared with the normal size of air samples the 5 $\mu$ 1 corresponds to about 100 ppm. Therefore at this attenuation of 5000, the gas chromatograph would not have seen these organic compounds at their maximum allowable concentrations. However, they should have appeared on the chromatograms where the four mystery peaks were seen because these peaks were found at the attenuation of 1000. Independent charcoal samples of the chamber air were taken inside the chamber. These samples were collected with a low flow blower system in the 44 hours immediately following the experiment and while the chamber remained sealed. These samples were processed by R. A. Saunders of Navy Research Lab.

DEVELOPMENT

The apparent atmospheric contamination experienced in MESA I and the possibility that this was related to the ill-health of the crew, established new requirements in this area.

1. A development test program designed to determine the chemical nature of the contaminants and to identify their sources;
2. A revision in emphasis sampling with more long duration and chemical sampling;
3. Redefine abort concentration limits and action.

Immediately following the MESA I abort, the chamber was resealed to allow continued atmospheric sampling. Using the high sensitivity gain on the gas chromatograph, some baseline "wobble" was resolved into four peaks which were originally indicated to be unknown contaminants. The retention times for these peaks did not agree with any of the gases for which the instrument had been calibrated. Further analysis at all sampling points throughout the system indicated no change despite filters or burners that should have reduced organic vapors. Finally, a sample of room air and outside fresh air were tested and the same peaks were found. Pure carbon dioxide and pure oxygen gave the same peaks with greater magnitude. It was apparent that the mystery peaks were not cabin contaminants, but some anomaly resulting from the reaction of certain gases on the chromatograph column or pressure fluctuations. The growth seen in the peaks had been related to the increase in oxygen and carbon dioxide concentrations inside the chamber. When known and characterized, these peaks would not interfere with other analyses. Other contaminants would be superimposed on this four peak pattern.

Attention was turned to heavier organic molecules which would not be detected by the normal 25-minute analysis of the chromatograph. Runs several hours in length were made to allow time for high boiling-point compounds to elute from the columns. No new peaks were found. Before the chamber was opened several grab samples were collected and a 50-liter cylinder was filled with chamber air to a pressure of 60 psi for future analysis. Concurrent with the final 44 hours of chromatograph testing, freeze-out and charcoal-absorption samples were collected for future analysis. Also during the final testing a series of measurements was made with the Kitagawa Toxic Gas Detector which showed 0.5-ppm NO<sub>2</sub>, and all other tests were negative.

A yellow oily material was extracted from the condensate left in the humidity underflow at the end of the MESA test. The quantity was limited but enough material was extracted for separation by paper chromatography into at least two components and to show the presence of sulfur, nitrogen and ketonic structures.



A new source of similar but not completely identical yellow oil was discovered in the two respiratory silica-gel canisters. The silica gel was discolored from blue to green in a layer about 1/4-inch thick at both the up and down stream ends indicating the contaminant was present in the cabin air as well as within the respiratory system itself. The amount of yellow oil in the silica gel was considerably greater than was found in the condensate and an extensive chemical investigation was made on it.

Special effort was made to utilize all the available talent both within Boeing and throughout the country for analytical help in solving the MESA I contaminant problem:

Boeing Quality Control Laboratory ran an infrared spectrum of the chamber atmosphere in a 10-meter gas cell. Nitrous oxide was identified in addition to the normal atmospheric gases, water vapor and carbon dioxide. Gas chromatographic analysis of the yellow oil in either solution showed no unknown peaks within the range of the specific column and temperature employed.

The Army Explosives Research and Development Laboratory at Fort Belvoir ran a mass-spectrographic analysis of chamber atmosphere. Except for the presence of hydrogen, no unusual gases were detected.

Beckman Instruments, Fullerton, California, ran infrared spectra of the yellow oil. They reported that the oil was a mixture probably containing some free hydro-carbon together with one or more other unidentified organic compounds. Their analysis of the spectra indicated the following probable types of groups or bonds present: acid, ester, OH, carbonyl, aromatic.

Ray Saunders of NRL, Washington, D.C., analyzed the contents of a small charcoal canister which collected a sample during the 44 hours following the MESA I abort. His preliminary analysis indicated 18 chromatographic peaks from which he has identified trichloroethylene, carbon dioxide, short hydrocarbons, freon 12, carbonyl sulfide, chloroacetylene, ethylene chloride, acetaldehyde, carbon disulfide, and ethanol. His analysis of the silica gel from the air regeneration system identified the following compounds: primarily trichloroethylene and ammonia with smaller quantities of hydrocarbons, methyl chloride, ethyl chloride, ethyl ether, acetone, methanol.

The University of Washington Chemistry Department ran mass spectra on a liquid nitrogen freeze-out sample from the MESA I run and on the yellow oil. The freeze-out sample showed only air with a large amount of carbon dioxide. The spectra of the yellow oil was very complex indicating a mixture of substances. The primary peak was at 32 leading to the conclusion that the mixture was relatively rich in sulfur.

Galbraith Laboratories, Knoxville, Tennessee, furnished an elemental analysis of one of the two yellow oil components initially separated by paper chromatography. Based on their analysis of carbon, hydrogen and nitrogen, the yellow oil component, if a pure substance, would have a theoretical formula of  $C_{26}H_{35}O_5N$ . However, subsequent studies showed that the component sent for analysis was actually a mixture of compounds with this theoretical formula as the average molecular ratios.

The Boeing Materials and Processes Laboratory ran tests on two of the suspected materials in the chamber, neoprene flexible tubing and vinylite sleeving. Their analysis showed that the vinylite was basically polyvinyl chloride which is much more stable than the polyvinyl butyrate which it had been thought to be. They also found that the sleeving contained copious quantities of tri-cresyl phosphate as a plasticizer which is highly toxic when breathed.

Samples of the chamber atmosphere and condensate were mailed to MELPAR at NASA request. They reported that nothing was detected in the atmosphere sample, but that two cresol peaks and one unidentified peak were found by gas-chromatographic analysis using temperature programmed analysis of the condensate. Also, boron, copper, magnesium and sodium was detected in small quantities in the condensate by emission spectrograph.

The Boeing Bioastronautics Laboratories have conducted analytical studies of the chamber contaminants along two general lines. The first is chemical analysis of the yellow oil from the condensate and silica gel. From this, it has been deduced that the yellow oil is a mixture of six or more organic compounds containing significant elements or groups including sulfur, nitrogen, ketone, acid, ester, but with no one compound containing all groups.

The second area is the comparison of infrared spectra of the yellow oil and its components with known spectra and with spectra of compounds obtained by extraction or thermal decomposition of chamber materials. Spectra were run on extracts from the plywood, tile, cements, wiring, rubber tubing, paint, waste-reactor liquid and gas effluent, superoxide, fiberglass filters, and many other materials. It was found that a large number of materials gave off a yellow oily compound with a spectrum similar to an oxidized oil or fatty acid such as, for example, castor oil fatty acid. No two spectra were identical but appeared to fall in the same class of compounds. Similarly, the MESA I yellow oil appears to contain one or more compounds of this same type in addition to other compounds in different classes.

When it became apparent that a quick, simple answer to the toxicity problem was not forthcoming, steps were taken to begin an unmanned run preparatory to starting a new 30-day manned run. The run began August 20, 1963 with all systems functioning and soon developed a yellow oil in the condensate which was followed by measuring the UV absorption of the ether extracted samples.

After two days it was decided to shut down the different subsystems one by one, 12 hours apart, in an effort to determine the source of the yellow oil. The UV absorption did decrease during the shut-down procedure but the change was gradual and did not pinpoint the source of the contamination. Animals in the chamber during this four-day test showed no ill effects.

A second unmanned run was then initiated (September 3, 1963) with a plan to start each subsystem up one at a time. This was expected to show more conclusively which of the subsystems were contributing to the yellow oil contaminant. The unexpected result was that the overall trend was slightly downward despite the addition of each subsystem. A confirming test with only the air conditioner on for sampling purposes indicated a continuing gradual drop in contaminant level. This led to the conclusion that the source of the yellow oil was in the chamber furnishings rather than from one of the subsystems.

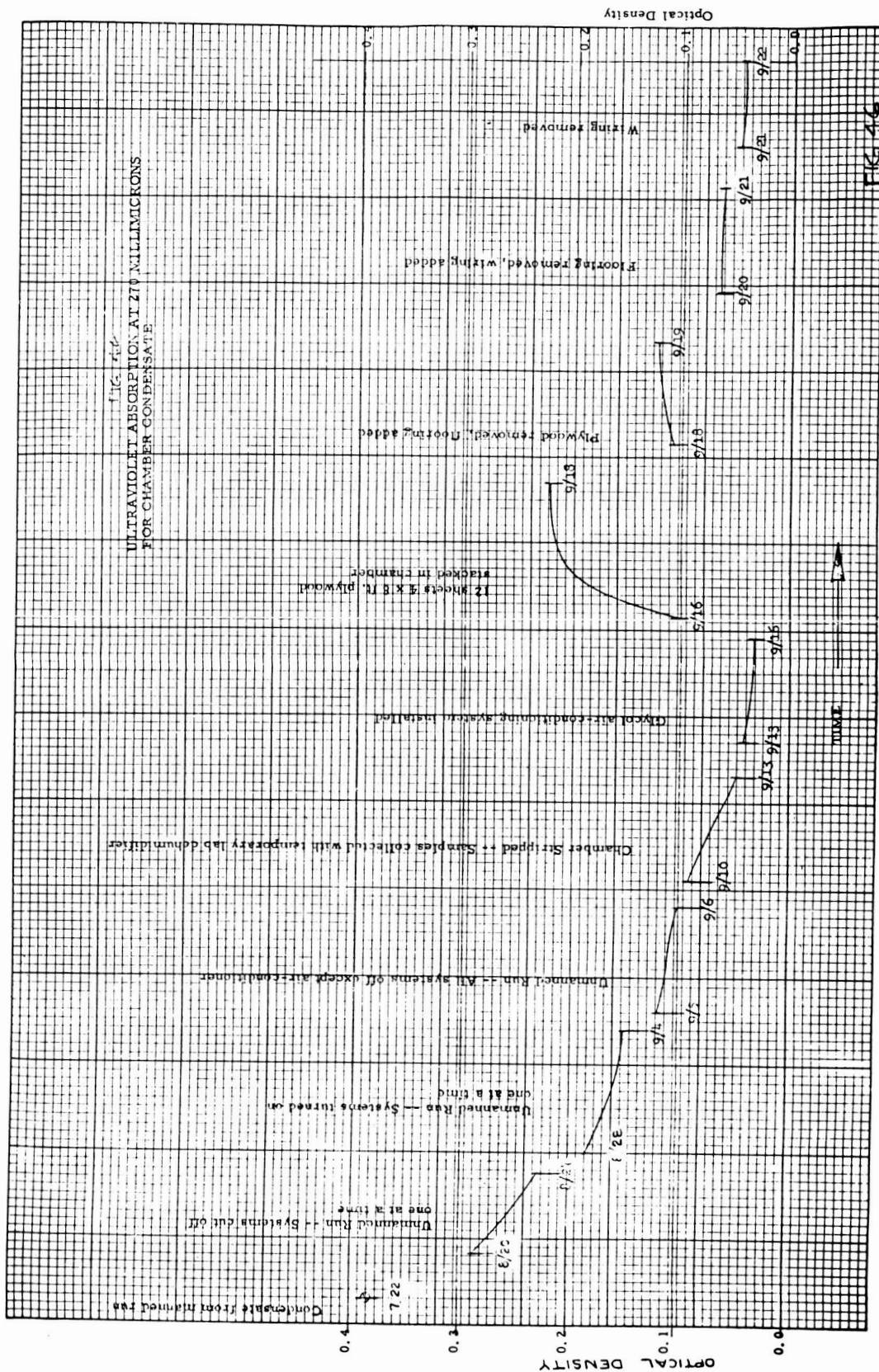
The chamber was stripped of all equipment and furnishings. Testing continued using a small commercial air conditioner unit to collect condensate samples. The UV absorption measurements dropped slowly to about .04 optical density. The regular air-conditioning subsystem was re-installed at this point and the optical density decreased to about .03 where it appeared to stabilize. It was assumed that the residual effect was due to the paint on the chamber walls. Samples of paint were scraped from the walls and ceiling and a yellow oil was extracted with ether. The infrared spectra of the extracted oils showed similarities to the MESA yellow oil but was not identical. Twelve sheets of plywood were stacked in the chamber to simulate the plywood cabinetry and equipment enclosures. This caused a rapid increase in optical density to .22 and indicated the plywood was a major contributor to the yellow oil contaminant. Again the infrared spectra was similar but not identical to the MESA yellow oil.

Several sections of the chamber flooring consisting of vinyl tile cemented to plywood were tested next. The optical density stabilized at about .12. Following the flooring a large bundle of wiring was placed in the chamber and the optical density dropped to about .06. A summary of the data from the condensate measurements is shown in Figure 46 .

In summary of the toxicology development program the following points are listed:

- a. Although highly suspect, atmospheric contaminants were not proven to be present in quantities which would produce toxicity.
- b. Analysis of the chamber atmosphere during and since the MESA I test has not shown any toxic gases; however, charcoal adsorption samples show a mixture of trace contaminants.

- c. A yellow oil found in the condensate and silica gel filters has been found to be a mixture of six or more organic compounds which have been partially characterized but not completely identified.
- d. A recent gas chromatographic test of the condensate by Melpar indicates cresol contaminants in the atmosphere but the concentration cannot be determined.
- e. The ability of the gas chromatograph to detect and measure trace contaminants has been shown to be limited and plans were made for more extensive use of less rapid but more sensitive methods in further tests.



Results from MESA I indicated that some changes in the gas monitoring were necessary. The direct sampling gas chromatograph did not give the complete coverage required. The trace contaminants required concentrating before they could be detected by our most sensitive instruments. For later tests the direct sampling instruments would be used for indication of contaminants only at higher concentrations. If necessary the contaminants in sub-detectable concentrations would be determined as a matter of record by the slower, more sensitive techniques of freeze out, adsorption and chemical testing. The concentrating techniques had worked well, but would be used more extensively.

Tests of the following nature were made with the Karmen Gas Chromatograph.

<u>Tests</u>	<u>Changes</u>	<u>Objective</u>	<u>Result</u>
Column Changes	Carbowax on Teflon  Carbowax on Chromosorb  Carbowax and amine on Teflon	Improve separations	Little Improvement
Sensitivity Tests	Injected various concentrations	Characterize sensitivity for compounds of interest	Table follows.
Sampled with Automatic Valve	(as opposed to syringe)	Determines effect of sampling valves	Precision improvement was slight.
Variation column	Frontal pressure varied from 30 to 60 psi with 15 to 25 psi drop across the column.	Obtain the best separation and sensitivity for each column.	Good operating conditions were developed.

Typical results from the tests (with 12' carbowax on Teflon column with the following conditions) were as follows:

Frontal P.	Back P.	Compound, Concentration	Retention Time	Peak Ht.	Alten.
30 psi	10 psi	Acetone, 240 ppm in H <sub>2</sub> ,	2.5 Min.	8 div.	$1 \times 10^4$
50	24	Acetone, 2400 ppm in H <sub>2</sub> ,	1.7	19.4	$1 \times 10^4$
50	24	Ethanol, 1500 ppm in H <sub>2</sub> ,	2.9 Min.	10.8	$1 \times 10^4$
40	25	Benzene, 1800 ppm in H <sub>2</sub> ,	6.6 Min.	13	$1 \times 10^4$

These tests were made by flushing the sample lines with a closed loop to a sample reservoir. The samples were taken with the automatic sampling valve. Reproducibility was adequate and drift was negligible in the single column mode of operation.

In summary, a general trouble shooting job was done on the gas chromatograph and all possible maintenance was performed. Performance level appeared to be adequate for the experiment.

#### c. Development of Concentrated Sampling Techniques

The flame ionization gas chromatograph was tested after changing the column, column oven, carrier flow control, injection system, recorder and fraction collector. Reproducible flow and retention time could be obtained over long periods and sensitivity was good.

1  $\mu$ l liquid acetone gave a deflection of 80 divisions on an attenuation of  $5 \times 10^3$ , 1  $\mu$ l liquid ethanol-off scale on  $2 \times 10^4$ , 20  $\mu$ l gaseous ether-off scale on  $10^5$ , and 0.1  $\mu$ l of gaseous ether 83 div. at  $2 \times 10^3$ . Stability was improved; attenuation could be set on 5 with little drift and less than two percent of full scale for noise. The following retention times are representative of the separations obtained with other 12 foot carbowax on chromosorb column: Ether - 2.3 min., formaldehyde - 4.3 min., Acetone - 6.8 min., Water - 13, Benzene - 15, toluene - 28.

A known sample mixture was desorbed on activated charcoal and desorbed into cold traps. The entrapped gases were fed into the gas chromatograph. All components of the mixture had been recovered.

Known samples were injected into the gas chromatograph. Fractions were collected in cold traps. The fractions were then warmed and transferred to a micro gas cell. Infra-red spectra were made. The 3 cm single path micro gas cell was not sensitive enough to give useable spectra for trace gases. A longer multipath gas cell was obtained.

In the laboratory investigation of the Hopcalite catalytic oxidizer and the waste disposal system,  $\text{NO}_2$  was evolved and measured. An ozone meter, the chemical absorption method and MSA detector tubes were used. Correlation was found. The meter generally gave higher readings for stronger concentrations than the chemical method, which was more sensitive for very low concentrations.

The concentrations, which require an immediate, mandatory abort of the experiment, were defined and the attached list was made. The long term MAC could be exceeded for short periods without danger to the subjects, but definite levels of contaminant concentration exist, above which immediate health and safety hazard exist.

With explosive gases, the abort limits were set at half the lower explosive limit. For toxic gases, the abort limits were set above the MESA MAC and just below the level where non-lethal symptoms might occur in the subjects within a short time.



## ABORT CONDITIONS -- CONTAMINANT LIMITS

### Explosive Gas Concentration Limits (50% LEL)

Hydrogen	20,000 ppm
Methane	25,000 ppm
Acetylene	10,000 ppm

### OTHER GAS CONCENTRATION ABORT LIMITS

Carbon Dioxide	50,000 ppm
Carbon Monoxide	500 ppm
Ammonia	1,000 ppm
Methanol	1,000 ppm
Ethanol	10,000 ppm
Propanol	5,000 ppm
Formaldehyde	25 ppm
Acetaldehyde	500 ppm
Acetone	5,000 ppm
Benzene	100 ppm
Toluene	1,000 ppm
Hydrogen Sulfide	200 ppm
Nitrogen Dioxide	50 ppm
Ozone	5 ppm

The instruments would be used in the following manner:

<u>Instrument</u>	<u>Gas</u>	<u>Purpose of Monitoring</u>
Karmen Gas Chromatograph	All	Constant surveillance, Functioning of subsystems, Potential Health Hazards.
Concentrated Sampling Techniques	All	Concentrate subdetectable amounts. Collect permanent Samples.
Paramagnetic Analyzers	O <sub>2</sub>	Continuous record.
Non-dispersive Infra-red	CO <sub>2</sub>	Continuous record.
NASA Charcoal Samples	All	Representative overall samples. Use specialized techniques and equipment of other Laboratories.

The gas sampling lines were polyethylene within the chamber to minimize the effect of sterilization or reaction with the microorganisms or trace contaminants. Outside the chamber, the sample lines, which went to the microbiological samplers, chemical detectors and concentrated sampling traps, were also polyethylene. The lines for the direct sampling instruments such as the oxygen and carbon dioxide analyzers and gas chromatograph were made of quarter inch copper tubing. The average length of line was 20 feet which gives a definite lag time to direct analysis. The longer lines would reduce microbiological counts. The lines attached to the various



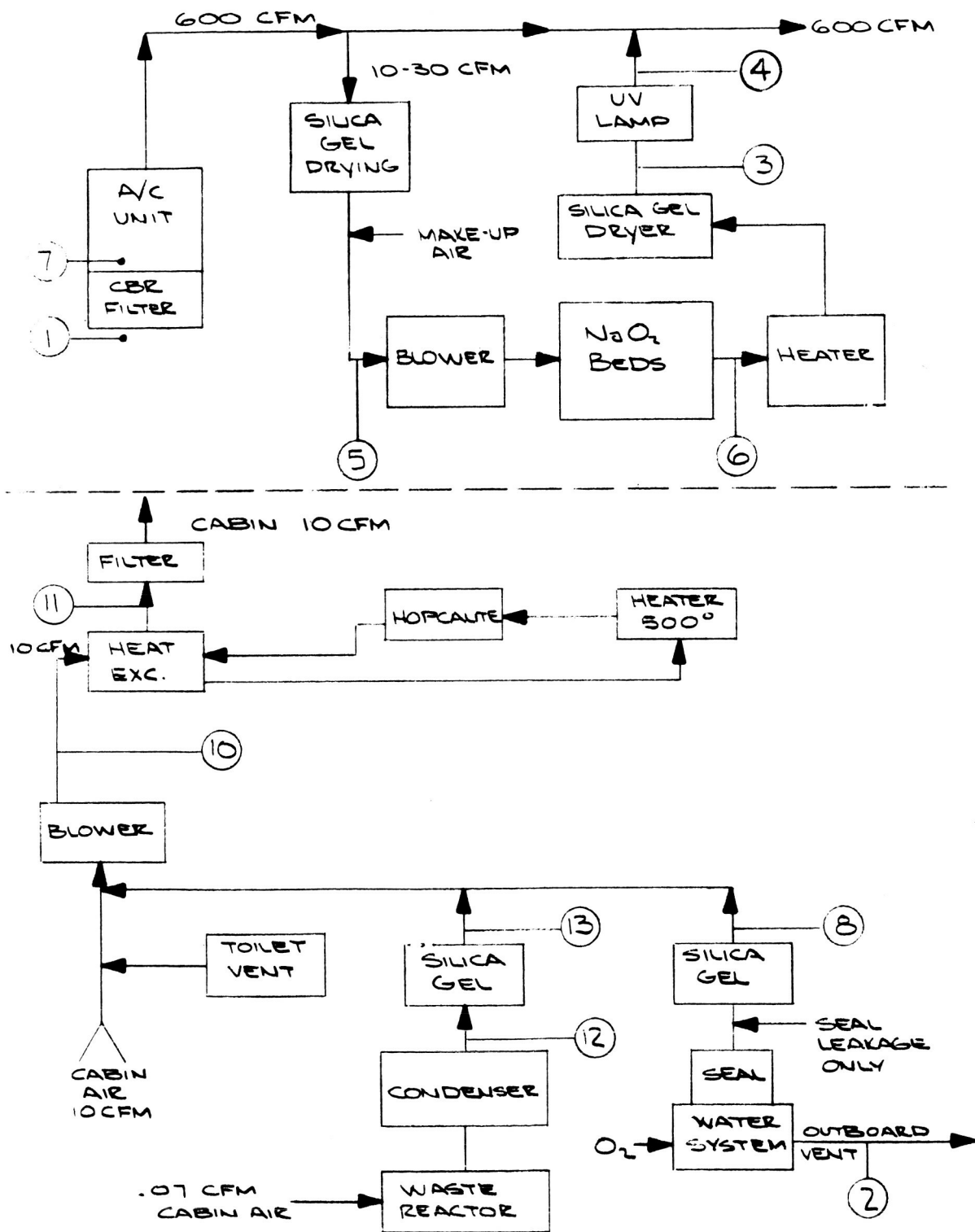
systems in the chamber were attached directly in the wall of the duct. No effort was made to sample from the center of ducts - which would have given more representative samples for both micro-biological contaminants or particulate matter. Sampling chart is Figure 47.

The Chromatograph was not giving its full potential but could probably be improved during the integrated testing before manned testing began. Optimum operating conditions for the partition and adsorption columns had not been found, however, useable data and needed detection could be obtained with the instruments.

# GAS SAMPLING CHART

MESA II

FIGURE 47



## SYSTEM TEST

### A. The 17-Day Experiment

1. The Mast Ozone meter monitored chamber air continuously while the chemical method determined the nitrogen dioxide concentration before and after the Hopcalite, waste disposal and superoxide systems. Both the Hopcalite and waste disposal systems were confirmed to be possible sources of nitrogen dioxide. Thereafter chemical samples were taken periodically at the sampling stations from chamber, the Hopcalite and the waste disposal systems. The chemical bubblers were found to be inefficient for high concentrations of nitrogen dioxide unless the tubes were run in series. More efficient dispersion tubes were prepared for the final test.
2. The Karmen Detector Gas Chromatograph did not sufficiently separate ammonia and carbon dioxide. A more efficient column of carbowax and armine on Teflon was ordered from the manufacturer.
3. Concentrated Samples

One charcoal sample was processed and analyzed. The desorbed mixture gave the chromatographic peaks at the following retention times:

<u>Time</u>	<u>Attenuation</u>	<u>Possible Contaminants</u>
1.6	50(i)	Air
2.6	100	Ether, acetic acid
3.8	100	Acetaldehyde (formaldehyde)
6.0	100	
6.8	100	Acetone
8.2	10	
12.8	50(i)	Water
14.6	100(sh)	Benzene, methanol

(i) - an inverted peak

(sh)- shoulder

A liquid nitrogen freezeout sample was processed. This gas mixture absorbed in the Infra-red with peaks corresponding to Carbon Dioxide and Nitrous Oxide. On the gas chromatograph the peaks were obtained at 6 minute, 12.7 minutes, and 24.4 minutes indicating the possibility of acetone, water vapor, and toluene.

### B. Changes in Between 17-and 30-day Experiments

1. The Karmen detector gas chromatograph was tested with a different column. Excessive noise was experienced part of the time.

2. The flow of the sample gas through the paramagnetic and infra-red instruments was changed. Restrictors, pumps and instruments were arranged to give a constant pressure in the instruments. When properly balanced for pressure, one pair of instruments would match the readings of the other pair for the same sample gas.
3. Originally the concentrated sampling board was plumbed for 10 concentrated samplers. Two chemical samplers were set up separately. With the added emphasis on nitrogen dioxide sampling, the chemical bubblers used the two plus five of the concentrated sample stations. The greatest need for concentrated samples was handled by the station for chamber air and the one after the superoxide. In the event of malfunctioning systems, more samplers would have been required.
4. With the success of the external apparatus for the taking of the NASA gas mask sample, a duplicate arrangement was made. This gave the capability of taking two separate gas mask canisters samples on any stations as well as the two internal chamber gas mask canisters, if emergency situations required it.
5. Standard Gas Mixture

A pressurized bottle of known gas composition was used to calibrate the gas chromatograph. On hand were the bottles from the manufacturer which were not certified nor analyzed standards. There was evidence that valve leakage had allowed the composition to change. A new standard gas with a certified analysis was purchased.

#### C. 30-Day Manned Test

##### 1. Concentrated Sampling

The samples were collected by a 200 cc/minute air stream drawn through the charcoal or freezeout trap. The sample gases were then transferred by heating into the freezeout collection traps. Samples were taken from the collection trap and injected into the hydrogen flame gas chromatograph or the multipath infra-red micro gas cell. A number of gases were separated as shown on the accompanying table for chamber samples, which covers the entire 30-day period, see Figure 161.

The retention times obtained from the samples from stations in the superoxide air or following the CBR filters were the same as those in the chamber samples but of less magnitude, showing some contaminants were removed by these systems.

The earlier samples contained less gases than later ones indicating a gradual buildup of some of the contaminants.

A sample of the charcoal from the CBR filter was desorbed. The gas peaks which were eluted show that the filter removed

typical chamber air components, but also peaks at 8.5 and 10.2 minutes, which must have been completely removed from the chamber air.

Further work would be required to make positive identification of these sample fractions. The samples of waste reactor and water treatment exhaust gases showed many more peaks and at higher concentrations than chamber air. This shows the effectiveness of the CBR filter, the silica gel filter, and Hopcalite burner in removing these trace contaminants. It also shows the reason for venting the water treatment system overboard. The charcoal samples in the NASA gas mask canisters were sent to other laboratories. The results have not been returned at this time.

The number of concentrated samples which were obtained during the test were as follows:

- 10 Charcoal of chamber air
- 10 Charcoal of superoxide air
- 5 Freeze-out of chamber air
- 1 Freeze-out of air filtered by CBR filter
- 1 Freeze-out of waste reactor air
- 1 Freeze-out of water treatment air
- 32 Gas mask charcoal samples of chamber air (NASA)
- 3 Charcoal from subsystem filters

## 2. Instrumentation

With the variety of possible trace contaminants, a number of instruments and procedures were required for analysis. The most versatile of all the instruments was the Beckman Gas Analyzer which contained a paramagnetic instrument for continuous oxygen monitoring, a non-dispersive infrared instrument for continuous carbon dioxide monitoring, and a process type gas chromatograph with Karmen Detector which could analyze for most of the probable contaminants. The first two instruments were set up to continuously monitor the chamber atmosphere while the gas chromatograph was programmed to sample at a series of points throughout the chamber. In addition extra oxygen and carbon dioxide instruments monitored at the various sampling points with the gas chromatograph. Another instrument used was the mast ozone meter for ozone, nitrogen dioxide and other oxidizing gases.

The paramagnetic oxygen analyzer models F-3 (recording) and E-2 (manual) operated with stability and accuracy. During the frequent calibrations they seldom required rezeroing or respanning, and then only by a few hundredths of a percent.

The non-dispersive infra-red analyzers for carbon dioxide, Beckman Model 15A and MSA Lyra 300, gave accurate stable readings.

The Beckman Process Gas Chromatograph Model 520E with Karmen type detectors did give a qualitative capability of continuously monitoring a series of sampling points but did suffer from the following limitations:

- (a) The gas chromatograph was supposed to analyze for all of the gases so indicated on the MAC chart (Page 134). The performance indicated less than this. Limited by the fact that trace contaminants were kept to a minimum in the chamber, the GC could only be checked against the known mixtures. Time was not available to inject a number of known organic vapors. The known mixture which was used was certified to contain .005% CO, .0099% CH<sub>4</sub>, .015% NH<sub>3</sub>, .03% H<sub>2</sub>, .5% O<sub>2</sub>, 39.7% O<sub>2</sub>.

The G.C. could separate the CO and CH<sub>4</sub>, but did not give reproducible readings for successive samples. The values varied by as much as a factor of three. The peaks for H<sub>2</sub> and NH<sub>3</sub> were not seen. On samples of the chamber air, CO<sub>2</sub> and water were identified, but the results were not quantitative.

- (b) The reading of the instrument was made difficult by a variable drift in the baseline from one side of the chart to the other. Accompanying the drift was a variation in gain. The drift appeared to be cyclic at times, but had a variable period.
- (c) The problems of (a) and (b) made calibration difficult if not impossible at times. A number of samples had to be run for each calibration and the average value was used with an allowance for the drift. This meant additional time off stream from the monitoring duties amounting to about 3 hours per day.
- (d) Noise covered much of the data and problems during the early days of the experiment. A new partition column, supplied by the manufacturer, apparently produced excessive bleed, which poisoned the detector for that column. Repeated cleaning of the detector was required during the first week and once every several days thereafter. The nature of the noise was an arcing, which caused the recorder pen to jump or oscillate from 10 to 50 scale divisions for fractions of a minute at frequent intervals up to continuously for several minutes. The cleaning of the detector accounted for an additional down time of 4-6 hours per week.

- (e) An alcohol spill similar to that of the 17 day run was not seen by this partition column.
- (f) When the partition column was run with samples at a high sensitivity, such as 1000, four peaks would occur in the same locations despite the origin of the sample. These peaks were apparently not caused by trace gases, but were due to the pressure pattern in the valves and column.
- (g) In summary, the gas chromatograph was used, but in its present configuration was not used to its fullest capability. The analytical data that was taken was sub-standard.

### 6.2.1.3 RECOMMENDED CHANGES IN THIS CONCEPT

#### A. Further Investigation of Limits

More data is necessary for the improvement of Maximum Allowable Concentration Limits for 24-hour-a-day exposure for prolonged periods. The toxicological effects of mixtures of small concentrations of gases may affect sensory perception and performance, but further study is required. Animal and manned studies could be performed to determine threshold and sub-lethal effects.

#### B. Further Samples Processing

From the concentrated sampling, some data has been gathered, but further valuable information could be gained by a detailed processing of more of the samples. With sufficient time and equipment the identification of every component of the samples could be made.

For future testing a separate funding should provide for the work to continue for a long enough period past the end of the chamber test to allow for the complete processing of trace contaminant samples. A period of several months would be required if there are numerous samples containing many contaminants.

#### C. Further Investigation of Detection and Analysis

The MESA tests utilized a single type of gas chromatograph in a single configuration. Many other columns, detectors and arrangements could be tried. The versatility of gas chromatography has not been fully exploited. Column dimensions, sample size, and pressures could be varied to improve the sensitivity of the method. Future chamber testing should allow for a developmental period for the gas analysis, and a thorough exploitation of equipment.

Quantitative aspects of the analysis can be perfected after the instrumental configuration is set.



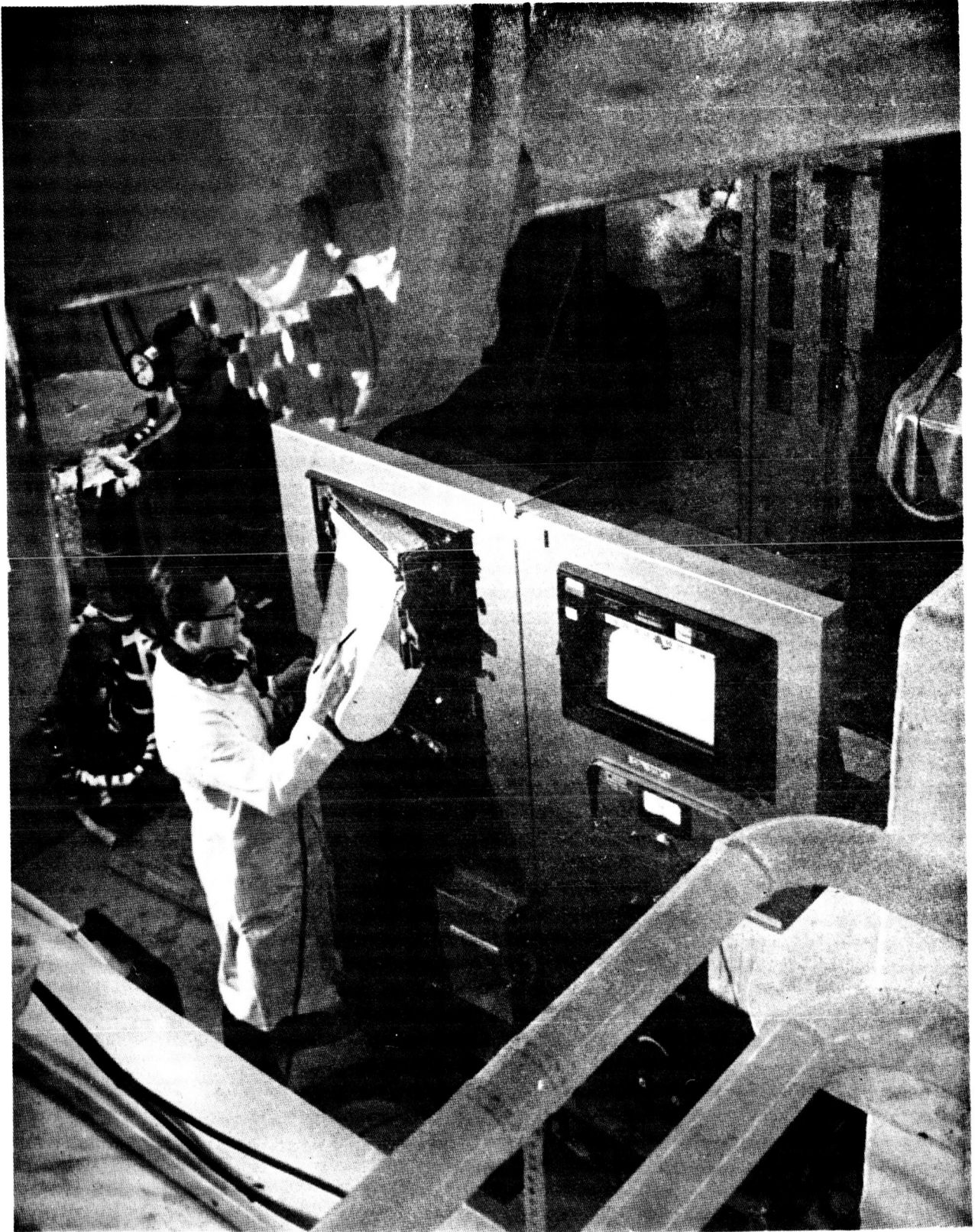


Photo 26: ENVIRONMENTAL MONITOR STATION — GAS CHROMATOGRAPH

FIGURE 48

## 6.2.2 BACTERIOLOGY

### 6.2.2.1 MESA I

#### DEVELOPMENT

A development program was undertaken to include UV lights for bacteria kill on the water and air systems.

Sterilization by ultra-violet light cannot reach 100% theoretically, but only approach it. The UV dosage required to kill 90% of most bacteria, viruses and yeasts ranges between 1,000 and 20,000 micro watt seconds/cm<sup>2</sup> exposure. A 4,000 micro watt second/cm<sup>2</sup> exposure provides a 90% kill for more than half of 34 organisms listed in the third edition IES Handbook with a minimum of 40% kill for the most resistant bacteria. In a recycling air system such as MESA's where the total cabin air is recycled about once an hour, a 4,000 micro watt second/cm<sup>2</sup> exposure is considered adequate. This should lead to an equilibrium airborne population approximately 20% above the average hourly rate of production. A 4,000 microwatt second/cm<sup>2</sup> dose can be obtained from a G30T8 ultra-violet lamp (General Electric) mounted concentrically inside a 10 inch duct or by two lamps in tandem in a 5 inch duct as well as other combinations. For the MESA run, a 36-inch ultra-violet lamp (G30T8) will be mounted concentrically in a 10-inch diameter pipe or plenum just ahead of each silica gel dryer unit. This will provide about 6000 micro watt seconds/cm<sup>2</sup> UV dosage assuming a reflection factor of 50 per cent.

Ultra-violet sterilization of clear distilled water can be considered in the same manner as air sterilization. The presence of pigments, suspended solids or certain dissolved substances can make the water highly opaque to ultra-violet light and prevent adequate sterilization. With the recycled water anticipated in the MESA system, a very high dosage rate will be easily attainable because of the low flow rate of approximately 1.0 to 1.5 liters/hr. Assuming that a G30T8 ultra-violet lamp is mounted concentrically in a 2-inch pipe or trough with the lamp just above the liquid surface, a  $5 \times 10^6$  micro watt second/cm<sup>2</sup> exposure will be obtained. Such high dosage rates should not be necessary for adequate water sterilization in the MESA system. A G15T8 ultra-violet light mounted as above would yield approximately half the dosage of the G30T8 lamp and should provide adequate water sterilization for this system. For the MESA system a G15T8 ultra-violet lamp was mounted in a trough at a 2 inch distance from the water level. The water depth in the trough was 0.6 inches. The trough was baffled to decrease the water flow rate past the UV light.

The MESA water system UV assembly was tested to determine the efficiency of the UV light dosage. The test organism used was Escherichia coli, a common fecal contaminant. Numbers of viable cells were estimated by dilution and plate count techniques. Suspensions of the organism in distilled water were run past the lamp at rates which varied from 3 to 6 times the rate at which water would flow during actual operation of the system.

<u>Flow Rate</u> (ml/min)	<u>Organisms Added</u> (cells/ml)	<u>Organisms Recovered</u> (cells/ml)
50	$8.0 \times 10^8$	0
75	$6.3 \times 10^7$	0
100	$7.6 \times 10^7$	19

These results demonstrate that the U-V system as designed effectively destroys E coli in a water stream.

#### SYSTEM TESTS

The 30-day manned attempt test did not last long enough for an adequate study of the environment on bacterial contamination.

As to be expected, viable bacteria similar to those found in the waste disposal reactor were found in high concentrations on exposed surfaces throughout the chamber subsequent to rupture of the waste disposal tank. Samples of water taken for bacteriological analysis were free of E coli and S fecalis, the common fecal contaminants. The only bacteria found in the water were common airborne contaminants.

#### 6.2.2.2 Bacteriology MESA II

Bacteria monitoring for MESA II included air, water, and surface sampling for the 17-Day Integration test and the 30-day manned test, and a special aerosol test right after the 17-day test.

#### AIR SAMPLING

##### A. 17-Day Integration Test

The Andersen 6-stage sieve-type sampler was used to take all air samples for viable bacterial counts. Sampling was done from the outside of the chamber using hose connections running through the chamber wall to the different sampling probes. All of the air sampled was pumped back into the chamber.

Tryptone glucose extract agar (DIFCO) was used in the Andersen glass plates as the collecting medium. After the samples were taken, the petri dishes were incubated at 27°C for 48 to 72 hours. Viable counts were made by assuming each colony growing on the petri dish represented one bacterium impacted there by the sampling techniques.

During the 17-day test and during the aerosol run, some leakage was found occurring around the gaskets sealing the six stages. The leakage was caused by the pressure differential between the inside and outside of the chamber and by the small diameter tubing used on the air return lines. The leakage was stopped by lapping the metal sealing edges of the six stages and by greasing the rubber gaskets with Dow Corning 55 pneumatic grease. Also, the lines returning air to the chamber were

replaced by 1/2-inch inside diameter Tygon tubing.

A diaphragm type compressor was used to pull air from the sampling ports through the sampler and to return the air to the chamber. A rotometer was installed in the line to insure a flow of one cubic foot per minute through the sampler.

Due to the leakage of the sampler, all results from the 17-day test air sampling are underestimated and are not reported.

#### B. Aerosol Test

Two aerosols, one containing Serratia marcescens and one containing Bacillus globigii were separately injected into the chamber to obtain preliminary information on the effect of subsystem components on bacterial longevity. The aerosol was generated over a twenty-minute period at the inlet to the air conditioning blower. The CBR Filter was removed and all equipment inside the chamber was inoperative except the system blowers. The main air flow rate was 600 cfm, that across superoxide beds was 20 cfm, and that across the unheated Hopcalite burner was 10 cfm. An Andersen sampler was used for periodic air sampling. The surfaces inside the chamber were sampled periodically by the Rodac plate method. A total of 20 square inches per surface was sampled.

The results of the S marcescens aerosol are shown in Tables 2a and 4. Both the superoxide and the Hopcalite appeared to remove S marcescens from the air. Recovery of S marcescens from the chamber surfaces was extremely low. Either the organisms died quite rapidly or were impacted on the surfaces of the air conditioning system duct work.

The results of the Bacillus globigii spore suspension aerosol are shown in Tables 3 and 5. The superoxide beds were apparently not as efficient as the Hopcalite in the removal of B globigii spores. Recovery of B globigii from the chamber surfaces was extremely high. All air samples were underestimated due to leakage in the Andersen samplers.

<u>Sample Station</u>	<u>Time of Air Sampling After Aerosol Generation</u>					
	<u>1 Min.</u>	<u>1 Hr.</u>	<u>2 Hrs.</u>	<u>3 Hrs.</u>	<u>4 Hrs.</u>	<u>24 Hrs.</u>
Cabin Air	53	0	0	0	0	0
Before NaO <sub>2</sub> Bed	118	0	0	0	0	0
After NaO <sub>2</sub> Bed	1.4	0	0	0	0	0
Before Hopcalite	9.8	0	0	0	0	0
After Hopcalite	0.2	0	0	0	0	0

TABLE 2a

NUMBER OF S MARCESCENS/CU.FT.

<u>Sample Station</u>	<u>Time of Air Sampling After Aerosol Generation</u>			
	<u>1 Min.</u>	<u>1 Hr.</u>	<u>2 Hrs.</u>	<u>24 Hrs.</u>
Cabin Air	524	8	0.4	0
Before NaO <sub>2</sub> Bed	252	99	4.7	0
After NaO <sub>2</sub> Bed	29	92	0.4	0
Before Hopcalite	326	0	0.9	0
After Hopcalite	0.2	0	0	0

TABLE 3

NUMBER OF B GLOBIGII/CU.FT.

Surface Sampled	Number of <u>S. Marcescens</u> per 20 sq.in. of Surface		
	Time of Surface Sampling After Aerosol Generation		
	20 Min.	4 Hrs.	24 Hrs.
South Bunk Air Inlet	0	0	0
Lower North Bunk Air Inlet	3	0	0
South Bunk Mattress	-	0	0
Bunk Area Floor	-	0	0
Entrance Area Air Inlet	7	1	0
Entrance Area Shelf	40	0	0
Entrance Area Floor	-	1	0
External Surface of Audio- Visual Booth	-	0	0
Command Station Air Inlet	14	0	0
Command Console Surface	5	0	0
Command Station Storage Back	-	1	0
Command Station Floor	-	2	0
CBR Filter Inlet	TNC	TNC	3
Floor Around CBR Filter Inlet	-	0	0
Air Inlet Near Recreation Area	13	0	1
Surface of Water System Cabinet	0	0	0
Air Inlet Near Waste System	16	0	0
Surface of Food Prep. Cabinet	-	0	0

---

TNC - Too Numerous to Count.

TABLE 4  
CHAMBER SURFACE SAMPLING AFTER GENERATION OF S. MARCESCENS AEROSOL

<u>Surface Sampled</u>	<u>Number of <u>B globigii</u> per 20 sq.in. of Surface</u>		
	<u>Time of Sampling After Aerosol Generation</u>		
	<u>20 Min.</u>	<u>2 Hrs.</u>	<u>24 Hrs.</u>
South Bunk Air Inlet	5	2	3
Lower North Bunk Air Inlet	5	2	9
South Bunk Mattress	33	102	280
Bunk Area Floor	121	TNC	TNC
Entrance Area Air Inlet	30	44	52
Entrance Area Shelves	143	TNC	TNC
Entrance Area Floor		TNC	TNC
External Surface of Audio- Visual Booth		4	6
Command Station Air Inlet	TNC	58	99
Command Console Surface	117	TNC	196
Command Station Back	TNC	TNC	TNC
Command Station Floor		TNC	TNC
CBR Filter Inlet	TNC	TNC	TNC
Floor Around CBR Filter Inlet		TNC	200
Air Inlet Near Recreation Area	TNC	143	TNC
Surface of Water System Cabinet	11	35	41
Air Inlet Near Wash System		TNC	TNC
Surface of Food Prep. Cabinet		TNC	TNC

---

TNC - Too Numerous to Count.

TABLE 5  
CHAMBER SURFACE SAMPLING AFTER GENERATION OF B GLOBIGII AEROSOL



### C. 30-Day Test

During the 30-day manned test, bacteriological samples of the chamber air were taken using the same methods as for the 17-day test. Air was taken from 8 different gas sample ports. The numbers assigned to the air ports and a description are shown on Figure 47. Table 6 shows the data collected for 6 different days during the test.

The air sampled from port 7 shows that practically no bacteria were passed through the CBR filter. The results from ports 3 and 4 give some indication of the effect of the ultra-violet light, particularly on Day 9 where the viable counts show a decrease from 0.9 to 0.1 organism/cubic foot of air after passing through the ultra-violet light. The viable counts were large from port 10, which would be expected considering the waste reactor as the source. However, the air, after passing through the Heat Exchanger and Hopcalite Burner, became bacteriologically ultra-clean air and was then returned to the cabin atmosphere. The results from the sampled cabin air indicate the men were living in a relatively bacterial clean atmosphere for the entire 30 days.

TABLE 6

## BACTERIA AIR SAMPLING RESULTS FROM 30-DAY TEST

Day	Sampling Ports							
	1	3	4	5	6	7	10	11
Day 4								
A	30	30	30	30	30	30	30	30
B	9	0	0	2	1	1	114	3
C	0.3	0	0	0.07	0.03	0.03	3.8	0.1
Day 9								
A	30	30	30	30	30	30	30	30
B	176	4	27	8	0	0	595	0
C	5.9	0.1	0.9	0.3	0	0	19.8	0
Day 13								
A	15	20	20	30	30	30	5	30
B	36	0	1	1	2	1	569	0
C	2.4	0	0.05	0.03	0.06	0.03	113.8	0
Day 20								
A	15	20	20	30	30	30	2	30
B	16	3	1	2	5	1	106	0
C	1.07	0.15	0.05	0.07	0.17	0.03	53	0
Day 25								
A	15	20	20	30	30	30	2	30
B	12	0	0	0	0	0	30	0
C	0.8	0	0	0	0	0	15	0
Day 30								
A	15	20	20	30	30	30	2	30
B	30	0	0	2	0	0	16	0
C	2.0	0	0	0.07	0	0	8.0	0

A - Total Cubic Feet of Air Sampled.

B - Total Number of Organisms Recovered.

C - Number of Organisms per Cubic Foot of Air Sampled.

## WATER SAMPLING

### A. 17-Day Integration Test

Bacteriological samples of internal water system were taken at various days during the test. Total bacterial counts were taken on the water samples using Tryptone glucose extract agar and incubation at 35°C for 48 hours. The results are shown in the following table. The external holding tanks, W6, W7 and W10, were not pre-sterilized. This prevented an accurate assessment of the bacterial condition of the water produced. Difficulty was experienced with the sampling ports in the humidity underflow system, preventing sampling of W8 after the ion exchange and after the charcoal filter. This difficulty was rectified before the manned test.

As shown in Table 7, the U-V light was effectively sterilizing the water in the water system. Since the contamination prior to Dynion filter was unknown, its performance could not be accurately assessed.

<u>Water System</u>	<u>Number of Bacteria/ml</u>			
	<u>Day of Sampling</u>			
	<u>3</u>	<u>4</u>	<u>6</u>	<u>10</u>
Before Ion Exch.	17,300	3,750	67	3,950
After Ion Exch.	10,200	10,800	103	4,500
After Charcoal Filter	43,500	70,000	226	150,000
After U-V Light	0	0	0	0
External Hold. Tank #1	TNC	TNC	225	79,000
External Hold. Tank #2	TNC	TNC	320	
<u>Humidity Underflow System</u>				
Before Dynion Filter	Valve Inoperative			
After Dynion Filter	0	0		
External Hold. Tank	300,000	64,000		

TNC - Too Numerous to Count.

TABLE 7

BACTERIAL COUNTS OBTAINED FROM WATER INSIDE CHAMBER - 17-DAY TEST  
(After 48-Hour Incubation at 35°C)

## B. 30-Day Test - Internal Water

During the 30-day test, samples were withdrawn from selected sampling ports in the water system and in the humidity underflow system for bacteriological counts. The total number of bacteria were determined by plate-count technique using Tryptone glucose extract agar and 48 hours' incubation at 35°C. The results are shown in Table 8. As expected, a population of microorganisms was established on the ion-exchange resins and on the charcoal filters. A portion of the population developing on the water system cartridges was not destroyed by the U-V light.

The samples collected after the Dynion filter showed the presence of bacteria on Day 17 and continued to do so until the end of the test. This could be caused by a failure of the Dynion filter or by a backgrowth of organisms from the ion-exchange column. After the 30-day test, the Dynion filter was removed from the system and retested for bacterial filtration efficiency. The Dynion filter removed one-hundred percent of the bacteria from a heavy bacterial suspension in water.

Towards the end of the test, the potable water tank had a visible slime growth consisting of bacteria and an actinomycete on the bottom and lower sides of the tank.

	<u>Number of Bacteria/ml</u>				
	<u>Day of Sampling</u>				
	<u>11</u>	<u>17</u>	<u>23</u>	<u>26</u>	<u>29</u>
Before Ion Exch.	2	0	3,600	3,600	9,600
After Ion Exch.	34,000	17,000	2,200	2,500	14,100
After Charcoal Filter	5,000	30,000	4,700	2,400	5,600
After U-V Light	5,300	400	2,000	14,000	8,500
<u>Humidity Underflow System</u>					
Before Dynion Filter	6,200	2,800	500	4,000	4,200
After Dynion Filter	0	1,000	24,000	17,000	300
After Ion Exch.	--	260,000	41,000	860,000	33,000
After Charcoal Filter	166,000	1,000,000	56,000	16,000	135,000

TABLE 8

BACTERIAL COUNTS OBTAINED FROM WATER INSIDE CHAMBER  
(After 48-Hour Incubation at 35°C)

### C. 30-Day Test - Potable External Water

The bacteriological limits for potable water were fixed at:  
a) 2.2 coliforms/100 ml using membrane filter procedure, and  
b) 25,000 organisms/ml using plate-count technique with Tryptone glucose extract agar and incubation at 35°C for 24 hours. Each day's final water collection from the water system and from the humidity underflow system were tested for potability. Coliforms were never present in the water system final water. However, on eight separate occasions during the third week, water from this system was rejected on the basis of total count. Rejection was attributed to decreasing effectiveness of the U-V light leading to bacterial growth in the system plumbing between the U-V light and the outside holding tank. These lines were sterilized with alcohol on Day 26. Subsequent water samples showed an increasing total count but did not reach rejection limits until the final sample.

The humidity underflow final water was rejected 5 times for coliforms, 6 times for total bacterial count, and twice for both coliforms and total count. To determine the source of coliforms in the humidity underflow final water, the spent ion exchange and charcoal filter cartridges were tested for the presence of coliform organisms. Out of 7 spent charcoal cartridges, 6 contained coliforms. One out of two spent ion exchange cartridges was positive for coliform organism. Since the coliforms could have been present on the cartridges when received from the factory, 6 new charcoal and 6 new ion-exchange columns were tested for coliforms. No coliforms were recovered from these new cartridges. A second probable source of the coliform contamination was the waste disposal laboratory where the charcoal filters were washed with distilled water before use in the chamber. Subsequent cartridges were washed in a clean area. However, the coliforms still appeared in the humidity underflow final water. Alcohol sterilization of the plumbing lines and replacement of the ion exchange and charcoal cartridges did not affect the appearance of coliform organisms in the system.

During the post-test debriefing, it was discovered that the sponges which had been used for spilled effluent were also used to wipe up the water spillage around the charcoal and ion-exchange filters when new cartridges were inserted. This practice was most probably the source of the coliform contamination.

#### D. 30-Day Test - Shower Water

The effectiveness of pasteurization of the shower water at 165°F for 30 minutes was determined by total bacterial counts. (Plate-count method - Tryptone glucose extract agar - incubation at 35°C for 48 hours.) Samples were collected prior to, and immediately after, pasteurization and after cooling to shower temperature (105°F).

W11 - After filtration, but before pasteurization.

W12 - From pasteurization tank.

W13 - At shower head.

Due to difficulties with the shower system, only three sets of samples were obtained. One set of samples was taken when soap had been used for the shower and the other two were taken when no soap was used. The results are shown in Table 9. These results indicate the pasteurization process was not as effective in the presence of soap as in its absence.

<u>Number of Bacteria/ml</u>			
	<u>Soap Present</u>	<u>Soap Absent</u>	
	<u>Water Temperature</u>		
	Ambient	Ambient	Ambient
W11	21,000,000	20,000,000	40,000,000
	<u>Water Temperature</u>		
	105°F*	105°F*	165°F
W12	3,000,000	270,000	34,000
W13	19,000,000	Contaminated	24

\* Pasteurized and Cooled.

TABLE 9

BACTERIAL COUNTS OF SHOWER SYSTEM WATER

### CHAMBER SURFACE

The surfaces inside the chamber were sampled for bacteria by the Rodac plate method. At each sampling period, 20 square inches of each surface were sampled. The same surfaces were sampled each time. Tryptone glucose extract agar was used as the recovery medium. The plates were incubated at 28-30°C for 48 hours. The results are shown in Table 10. The surface sampling results are rather unremarkable except to indicate that, in general, the surfaces were dirty.

	<u>Number of Organisms/20 sq.in.</u>				
	<u>Day of Sampling</u>				
	<u>4</u>	<u>12</u>	<u>19</u>	<u>26</u>	<u>29</u>
Living Area Rug	177	TNC	TNC	863	TNC
Floor Near Shower Entrance	675	TNC	TNC	TNC	TNC
Table	137	TNC	TNC	TNC	TNC
Personal Hygiene Sink	TNC	TNC	TNC	TNC	TNC
Command Console	101	86	221	188	201
Water Colset	TNC	TNC	TNC	TNC	TNC
Food Prep. Cabinet	TNC	Sp. NC	TNC	352	317
Head Set	TNC	TNC	TNC	TNC	TNC
Sick Bay	213	467	253	TNC	TNC
Sick Bay Floor	235	TNC	TNC	TNC	TNC

TNC - Too Numerous to Count.

TABLE 10  
RODAC PLATE SAMPLES OF CHAMBER SURFACES

RecommendationsA. Water

The water system and the humidity underflow system produced potable water with the limits set (i.e., a) 2.2 coliforms/100 ml using membrane filter procedure, and b) 25,000 organisms/ml using plate-count technique with Tryptone glucose extract agar and incubation at 35°C for 24 hours). Water from the water system was rejected during the third week of the run for total count because the U-V light was only partially effective in destroying the bacteria from the ion-exchange and charcoal cartridges.

To prevent bacterial growth in the potable water tanks, the system should contain a bacteriological filter before the potable water tank or the U-V lights should be placed around the tank. Another alternative is to impregnate the potable water tank with some type of biocide such as silver.

B. Air

The CBR filter and the Hopcalite burner kept the air bacteriologically clean and effectively prevented any buildup of bacteria from occurring in the chamber atmosphere. The Hopcalite burner effectively destroyed the bacteria aerosolized from the waste disposal system.



6.3 CREW

6.3.1 MESA I

The crew for the July 1963, 30-day attempt included:

Commander and Medical Officer - R. H. Lowry, M.D.	
Boeing	Age 42
R. J. Barnicki - NASA/Edwards	Age 27
Maj. E. F. Westlake/USAF	Age 45
C. M. Proctor/Boeing	Age 45
R. J. Farrell/Boeing	Age 25

As stated herein, the test time (4 1/2 days) was insufficient to derive any usable data relative to work-rest cycles.

6.3.2 MESA II

A. Five subjects participated in the 4-day manned run which concluded the 17-day integrated pre-test. They were:

K. S. Brossel / Boeing	Age 43
F. T. Santler/Boeing	Age 28
J. R. Welker/Boeing	Age 36
P. W. Trush/Boeing	Age 26
N. E. Johnson/Boeing	Age 21

B. The subjects for the 30-day manned test conducted in March 1964 were:

Commander - R. J. Barnicki - NASA/Edwards	Age 28
Medical Officer - Lt. Commander D. W. Robinson,	
M.D., Navy/Pensacola	Age 33
J. R. Welker - Boeing	Age 36
P. W. Trush - Boeing	Age 26
W. A. Swenson - Boeing	Age 26

The first two crewmen were supplied by NASA. Of the three Boeing employees, two, Welker and Trush, participated in the 4-day pre-test. Mr. Swenson was the back-up crewman replacing Mr. N. E. Johnson who was medically disqualified 6 hours prior to the start of the test on March 2, 1964.

All five subjects were brought on board approximately three weeks prior to the start of the 30-day manned run. During this period, time was spent on system familiarization, pre-test medicals and behavioral testing and a diet period of 8 days prior to test start.

### 30-DAY MANNED TEST

The internal crew was responsible for internal monitoring of equipment, maintenance of equipment and maintaining records of medical and nutritional data. Samples of the internal data sheets are included. One crewman was in constant communication with the test conductor on the outside at all times.

A work-rest cycle was established to provide for accomplishment of all the requirements of the test when considering the living area available. A four "off", eight "on" was used with nutrition handled by 4 meals per day. A sample of the MESA II crew schedule is shown on the following page. (The behavioral testing was reduced at Day 5 as noted in section 6.4.) This schedule provided 2 crews of 2 each and 1 crewman on a split schedule. Although not unanimous with all crewmen this schedule showed:

- A. Good on amount of sleep.
- B. Good for breaking-up work hours and, therefore, monotony.
- C. Pre-conditioning prior to test would have been advisable. In some cases it took 6 to 7 days to get adjusted to the schedule.
- D. All crewmen stated that some variety in the schedule would be advisable. Such as; reduced schedule on one day a week to simulate Sunday. This would probably break up the monotony and relieve the boredom.
- E. The crewmen were not highly motivated to a "great cause" as would an astronaut in space. However, they proved that scheduled work could be performed on an orderly and timely basis.

The crew were left on their own insofar as physical exercise was concerned. Two crewmen performed the 5 BX while others performed no set exercises. Although no physical degradation was noted in 30 days, there appears to be a real need for continued exercise.

Personal hygiene appears to be a very important aspect of space confinement. Due to the super-clean atmosphere all subjects developed a very sensitive sense of smell. Normal personal odors became a source of annoyance to the crew. Because of possible toxic effects no deodorants shaving lotions, etc. were allowed. Another source of annoyance was flatus. Since the trace control system was not instant acting, the effect was, according to the crew, longer lasting than normal.

# CREW SCHEDULE

Time	S U B J E C T S				
	C	A	B	D	E
00:00	RRRR	ESSS	ESSS	MMM	BBBB
01:00	MMM	SSSS	SSSS	RRRR	ESSS
02:00	BBBB	SSSS	SSSS	MMM	SSSS
03:00		SSSP	SSSP	MMM	SSSS
04:00	MMM	PFFF	PFFF	BBBB	SSSP
05:00	FFFF	MMM	BBBB	FFFF	PFFF
06:00			MMM		
07:00	ESSS	RRRR	MMM	ESSS	BBBB
08:00	SSSS	BBBB	RRRR	SSSS	MMM
09:00	SSSS	MMM	BBBB	SSSS	RRRR
10:00	SSSP	FFFF	FFFF	SSSP	MMM
11:00	PFFF		MMM	PFFF	FFFF
12:00	BBBB	ESSS	ESSS	RRRR	MMM
13:00	RRRR	SSSS	SSSS	MMM	ESSS
14:00	MMM	SSSS	SSSS	BBBB	SSSS
15:00	MMM	SSSP	SSSP		SSSS
16:00	BBBB	PFFF	PFFF	MMM	SSSP
17:00	FFFF	MMM	BBBB	FFFF	PFFF
18:00	MMM	RRRR		BBBB	RRRR
19:00	ESSS	BBBB	MMM	ESSS	HHHH
20:00	SSSS	MMM	RRRR	SSSS	BBBB
21:00	SSSS	MMM		SSSS	
22:00	SSSP	FFFF	FFFF	SSSP	MMM
23:00	FFFF	BBBB	MMM	PFFF	FFFF

E - Electrocardiogram  
 S - Sleep  
 P - Personal Hygiene  
 F - Eating  
 M - Monitoring (Command Console)  
 B - Experimental Booth  
 H - Housekeeping  
 R - Recreation

There were two major occurrences during the 30-day test. These possible stress periods should be considered when reviewing other data relative to the crew. On Day 5, the crew objected strenuously to the magnitude and number of psychological testing. To the personnel on the outside it appeared to be a "change or else" edict by the crew. This problem is discussed in Section 6.4. The other occurrence started on Day 22, and was related to why the 3-day hospitalization was required after the test was over. Certain members of the crew felt the "confinement" was unnecessary if they were in good health and there was a difference of opinion on what confinement meant. This problem was worked over a 4-day period. There were no apparent objections during the actual 3-day confinement; this could have been attributed to the excellent attention the crewmen obtained in the hospital.

All crewmen stated that greater attention should be put on proper crew selection, long term program association for familiarization, and on giving the crew a greater responsibility insofar as monitoring and running the systems. When considering future programs, planners should carefully consider crew selection and program association "tenure". Astronauts presently in training for space missions would provide properly motivated subjects who could accept the un comforts associated with long-term testing.

Four of the five crewmen have offered their impressions of the 30-day manned test. Basically each crewman was requested to give his impressions without an attempt to suggest any areas of discussion.

R. J. Barnicki (April 8, 1964)

The test, as a whole, was very successful with relatively few problem areas. The operations and test plan were well defined. People were well-motivated and trained in each of their respective fields of responsibility.

The area of motivation and training of subjects left much to be desired. It is my strong feeling that a crew should be selected from a larger group, at least six months to a year prior to the start of such a test. This crew and all alternates should work in specific areas of responsibility using design review meetings, or the like, to orient and inform the parties in all phases of the program.

The engineering portion of Project MESA is one of the areas that the people of The Boeing Company can be justly proud. The engineering group was well managed, skillfully staffed, and displayed great motivation to a job that was exceedingly difficult and, to a great extent, unknown. The medical coverage, without question, spared no effort to insure that the safety and well being of the crew would not,

in any way, be in danger or that a change in a crew member's health status would go undetected or unrecorded.

In the area of bacteriology, once again the people showed a dedication to good and meaningful research data. The problem areas, I felt, that should be granted further study are: crew selection and training, personal hygiene, food, communications, behavioral testing, equipment design and presentation, medical monitoring and data presentation, gathering, and read-out.

I wish to express my sincere thanks to the people of the Bioastronautics section on the successful completion of a challenging project, and am proud to have been able to contribute to their effort.

J. R. Welker (April 6, 1964)

Crew selection for the MESA run appeared to be, of necessity, a matter of both temporal and financial expedience. Future programs might well follow criteria already well established in the present Astronaut training programs. Crew training, a secondary concern in this systems test, was hampered by the press of time. A thorough-familiarity with the operation, maintenance and repair of the systems was experienced by all only toward the latter part of the test.

Adaptation to the work-rest cycle was evident by the end of week one for most. This strong adherence to routine appeared to extend itself through all phases of the work-rest cycle. Maintenance and housekeeping tasks, for example, were often performed automatically by the same individuals, regardless of rotated daily assignments.

Reading generally appeared to be the most common mode of recreation. For myself, further investigation of handicraft activities that did not require glue or paint would have been fruitful.

Failure to whole-heartedly accept the psychological program may well have been due to its being the sole part of the program that appeared expendable and therefore it received the brunt of antagonisms stemming from confinement, the Gemini diet, minor malfunctions of the systems, and all other largely -- in other circumstances -- petty irritations.

Inter-personal relations among the crew appeared to range the behavioral spectrum, but primarily on a covert level. After a "shake-down" period of perhaps several weeks a pretty fair equilibrium existed. Attainment of a smooth working relationship with test personnel outside the chamber appeared to be a problem from time to time.

In that comments on and evaluation of the life support systems appear elsewhere, it is perhaps sufficient to mention the trouble free operation of the respiratory system. Space-weight factors appear to have been paramount in the design of particularly the water purification and waste treatment systems in that each was forced to operate at near its maximal limit. Development of a waste reactor with a sufficiently flexible loading rate factor would have solved, for example, the shower recycling problem. Modular design considerations would facilitate maintenance and repair of all systems demanding continuous operation. Of extreme importance, design and procedure-wise, is the requirement for maintaining practically aseptic conditions throughout the living area. Investigation of the applicability of such sterilizing techniques as ultra high frequency, or of cleaning compounds amenable to processing by the waste reactor might be profitable.

An important facet of the conduct of the MESA run was the high level of confidence felt by the crew for the test personnel on the exterior. One problem faced by the crew stemmed from the lack of feed-back of test data related to both systems and individual functions. The writer, for one, felt a relatively strong sense of lack of contribution to the test on his part. A small laboratory aboard would have solved this problem nicely.

The twice-daily medical monitoring came to be somewhat tedious due to the generally fine state of health of the crew. This daily interchange might better be handled by the medical personnel involved. In regard to this and other communication with the exterior, a chain of command procedure would be invaluable.

From my own point of view, given reasonable assurance of the well-being of loved ones, selection of a trained, competent and dedicated crew, and elimination or modification of some items of diet, prolonged confinement and isolation is not perhaps the problem it has appeared to be.

P. W. Trush (April 9, 1964)

#### Water System

Most problems were in the defoamer motor, and specifically the bearing. Effluent line blocks may have been avoided by better removal of solids that collected in the bottom of the effluent tank. The drip pan under the water system was not accessible for cleaning.

#### Reactor

The plugged condition of the reactor air nozzles when removed late in run suggested a regular daily replacement. Solid materials collected

in the bottom of the effluent tank and may have caused plugging of inlet line to water systems. The reactor seemed stable with good action during last week of run using liquid pump No. 1.

#### Shower

The hot shower was a high point in the day, pleasant and relieved monotony. It should be continued, if possible, on isolation projects. All sump tanks, however, must be designed to drain completely and should be easy to remove and clean.

Water pumps continually lost prime and had to be manipulated to get water started.

#### Personal Hygiene Cabinet

The flat bottomed sump tank collected water and became rancid. Plex-glass cover warped and was difficult to replace. Sump was difficult to clean. The sump pump was modified during test to keep water at a lower level.

#### Head

Urinal tank was not easily cleaned. Sample valve at comminution unit held raw sewage, did not give a specific sample, and was not cleanable. Did not get a sample every time.

#### Psychological Testing

Midnight psychological testing was highly irritating and seemingly unnecessary. Originally over-scheduled, was reduced to less than an optimum level. I would suggest complete days off in the psychological testing area, such as weekends which would help reduce monotony.

#### Food

A tremendous relief was experienced by all crew members when the Gemini diet ended. The space station diet was far superior. More variety, more milk and juice is recommended. Although filling, the food did not "stick" long and hunger returned before the next meal. The low residue diet was a cause of flatus and continual physical discomfort.

#### Work-Sleep Schedule

I never adjusted comfortably to the 3 1/2 hour sleep, 8 hour work schedule. Noise level made falling asleep difficult. There could have been more work, i.e. involvement with the system itself. This would make sleep easier. A 5-hour, 2-hour sleep schedule is recommended plus a 6-hour period on weekends to break the monotony. The most normal schedule workable is the best, and less sleep is required in enclosed areas.

W. A. Swenson (April 10, 1964)

In my estimation the most important single upholder of morale in the chamber is food. Therefore, from a standpoint of desirability rather than nutrition I would suggest that it could be improved. A more flexible diet which could be varied to the consumer's wants would be very welcome. In lieu of this, at least a repetition schedule of greater than three days as in the space station diet. Most food needed salt, especially meat, which tended to be bitter.

At least in my waking hours there was not enough variety of schedule. The time at the command console varied one hour every other waking period allowing me one extra hour of rest before bed each 6:00 am. This I looked forward to with glee. While I do believe that a regularly repeated sleeping schedule is desired, the same chain of events day after day produces boredom.

It was mentioned to me that the shower system could possibly be replaced with a sponge. I think this would be unfortunate, especially in the case of a longer run. I should think some form of immersion system could be worked out to counter-act zero-gravity. The total lack of real three-dimensional water for bathing purposes would not seem to appeal to Americans.

In conclusion, I would say that I think the reactions of the crew to the manner in which the test was conducted, particularly in the area of relations of the inside to the outside, should be noted and would perhaps save hours of confusion and anxiety in future tests of this kind. A slight personality problem occurring for the moment within the chamber strangely enough feels much the same to the individuals concerned as it would outside the chamber and need not cause undue indigestion to the outer world. Of course, future experiments can produce future problems, but slightly more readiness to have confidence in the judgment of the crew concerning problems of health, personalities, etc., might result in a greater confidence of the crew in itself.



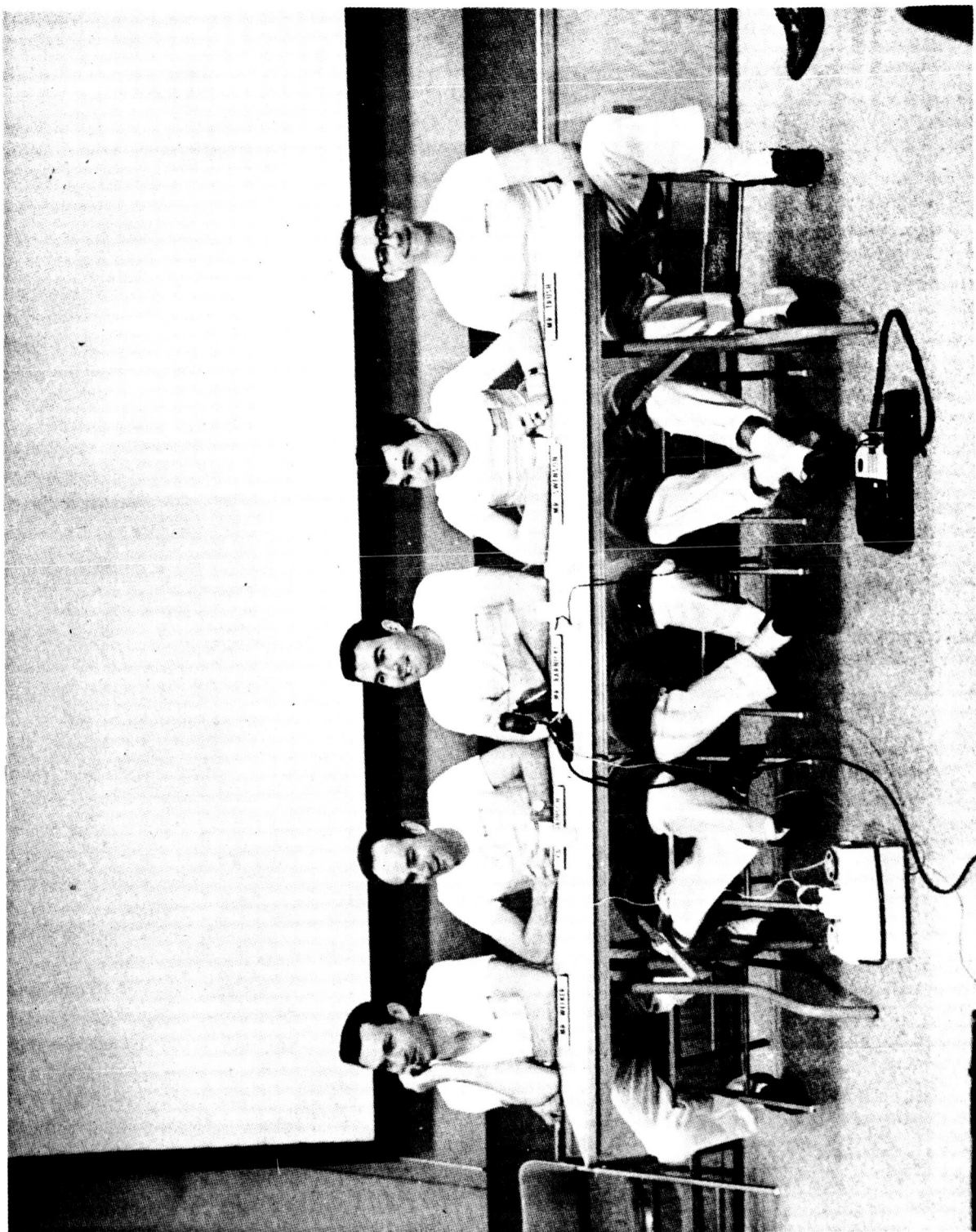


Photo 27: DEBRIEFING — MESA II CREW

# URINARY & FECES RECORD

Date \_\_\_\_\_

HOUR	TIME	A	B	C	D	E
1	00:00					
2	0100					
3	0200					
4	0300					
5	0400					
6	0500					
7	0600					
8	0700					
9	0800					
10	0900					
11	1000					
12	1100					
13	1200					
14	1300					
15	1400					
16	1500					
17	1600					
18	1700					
19	1800					
20	1900					
21	2000					
22	2100					
23	2200					
24	2300					

**TEMPERATURE - PULSE - WEIGHT RECORD**

DAY _____	MEAL	TEST TIME	TEMP.	PULSE	urine volume
SUBJECT A  _____ WEIGHT	1				
	2				
	3				
	4				
SUBJECT B  _____ WEIGHT	1				
	2				
	3				
	4				
SUBJECT C  _____ WEIGHT	1				
	2				
	3				
	4				
SUBJECT D  _____ WEIGHT	1				
	2				
	3				
	4				
SUBJECT E  _____ WEIGHT	1				
	2				
	3				
	4				

# WALK-AROUND DATA SHEET

Day: \_\_\_\_\_ Test Time \_\_\_\_\_

Comments

## Waste Disposal System

Reactor Level

Effluent Level

Pump Discharge Pressure

Hopcalite Heater Temperature

Reactor Temperature

Air Flow

Air Pressure

## Water Treatment System

Conductivity Cell C<sub>1</sub>

Conductivity Cell C<sub>2</sub>

Elapsed Time

Evaporator Pressure P<sub>2</sub>

Condenser Pressure P<sub>2</sub>

Potable Water Level

O<sub>2</sub> Flow

O<sub>2</sub> Bottle Pressure Check

Water Flow

Vapor Temperature T<sub>4</sub>

Evaporator Temperature T<sub>3</sub>

Evaporator Level Check

Conductivity Cell C<sub>3</sub>

Glycol Return Check

Foam Separator Check

Ultraviolet on Check

## Temperature and Humidity

Cabin Air Temperature

Glycol Inlet Temperature

Glycol Outlet Temperature

Air Discharge Temperature

Condensate Level

Subject Initial

COMMENTS:

## COMMAND CONSOLE DATA SHEET

DAY: \_\_\_\_\_

Test Time		+30		+30		+30		+30		+30
O <sub>2</sub> Concentration										
CO <sub>2</sub> Concentration										
CO Concentration										
NH <sub>3</sub> Concentration										
H <sub>2</sub> Concentration										
CH <sub>4</sub> Concentration										
Humidity to NaO <sub>2</sub> Bed										
Air Flow (Respiratory)										
Air Flow (Hopcalite Filters)										
Cabin Humidity										
Oxidizer Temperature										
Oxidizer Current										
Oxidizer Voltage										
Dryer Regeneration Temperature										
Subject Initial										

COMMENTS:

The behavioral assessment program during MESA I was comparatively small due to the amount of crew time which was taken up by maintenance and repair of the life support system, due to crew illnesses, and because of psychological apparatus problems.

Prior to the beginning of the run intelligibility, stereopsis, visual acuity, phoria, pitch discrimination and color discrimination were given to from one to four of the crew members. Pre-confinement tests which were given to all of the participants were the subjective stress scale (SSS) and the confinement questionnaire (Inventory I-A). Due to time limitations and to apparatus difficulties no other pre-confinement testing was carried out.

In addition to the above tests which were taken by some of the crew during the run, also included in the test program for some were complex information processing, the Nowlis Adjective Check List (ACL) and the Semantic Differential.

After the run was aborted some curtailed data collection was pursued. All crew members received the Modified NRL Scales, the Semantic Differential, the Nowlis ACL and the SSS. Some also received the stereopsis, phoria and visual acuity tests.

Because of the circumstances surrounding the collection of the behavioral data, much of this information would have to be viewed as highly unreliable. In addition, so many things happened during the run that the observed trends are difficult to interpret. For these reasons only a few general, highly speculative, findings will be mentioned.

Fairly early in the run the things that bothered the crew most (from a list of twenty-one items on the Modified NRL Scales) were: smells, food, toilet facilities, dirt and leadership. Administered again to tap feelings at the end of the run the Modified NRL Scales showed that in addition to smells, food and dirt, the behavior of other crew members, physical symptoms and the lack of water for washing were highly annoying features of the chamber environment.

The retrospective questionnaire (Inventory I-A and I-B) was designed to evaluate various experiential factors of chamber confinement. It consisted of statements which could be expected to apply both to normal living conditions and to life in the chamber. For the pre-confinement version each crew member checked each statement to indicate how much it applied to a typical week of his life. Later the crew members took Inventory I-B in which they indicated how the same statements had applied while they were in the chamber. Examples of the more than twenty factors contained within the questionnaire are: intellectual efficiency, unusual visual or auditory experiences,

restlessness, physical symptoms and complaints, concern over the passage of time, anger and hostility, lonesomeness, and worry or fright. Shifts in marking the individual statements from baseline experience to during the run were evident in very few instances. Examination of the item clusters making up the various factors revealed no pronounced during-confinement changes other than in the area of bodily symptoms and complaints.

There was some evidence that the crew members during confinement felt less comfortable and satisfied, that they found activities less pleasurable, that they did not feel fresh and rested upon awakening, and that they sometimes felt discouraged. They clearly did not like the food which was supplied. There was also some indication that the crew members were bothered by the slow passage of time and that they didn't wish to be bothered by tests during the confinement.

From the Nowlis Adjective Check List came some indications of mood changes while in the chamber. During the confinement experience as compared with before confinement, crew members increased in aggressive feelings and in depression and decreased greatly in the checking of words relating to pleasantness.

#### 6.4.2 MESA II

##### 6.4.2.1 REQUIREMENTS

Various psychological tests were used to evaluate the effects of a thirty day stay in the MESA chamber on the behavior of the five man crew. The extensive psychological measurement program which was originally developed was designed to serve the dual function of permitting assessment of crew performance as well as providing a large portion of the job load throughout the month's confinement. It later turned out that the work load required to maintain the life support system was sufficiently heavy that the need to "fill time" with extraneous tasks was considerably diminished. Hence, the final psychological test program was much abbreviated and had as its only major aim the assessment of potential behavioral changes.

The interest in crew behavior stems from a considerable backlog of anecdotal information and research literature suggesting that various behavioral changes can be brought about by unusual environments. The psychological assessment program was added late in the planning stages of the MESA project in order to discover any possible behavioral decrements which could have a bearing on the ability to complete future long-range space missions.

Several experimental problems or limitations should be mentioned since they served to limit considerably the utility of the behavioral assessment which was carried out. First, any crew is bound to be quite different from other crews and as a result the

individual and group behaviors reported here may be greatly limited in generalizability. Perhaps the most severe limitation is the fact that no control group could be employed to take the various tests on the same time schedule (as the MESA Crew) while leading a more "normal" life. Assuming that the behavior of such a control group would not have remained consistent throughout the run it is nearly impossible to interpret the rises and falls of crew behavior. To those aware of the many features of the complex MESA project it will be clear that another difficulty in results interpretation is the fact that changes in crew behavior could be attributed to any of a large number of aspects of the MESA environment, few of which could be adequately controlled. Finally, the subjects who were available for selection were, in most cases, different from the population of persons to whom generalization is desired. For this reason many of the sorts of problems discovered in this study might not be found among astronauts.

Keeping all of these limitations in mind, the data collected here can still be expected to be a contribution to the growing literature of long term group confinement as well as furnishing valuable hypotheses about potential "people problems" in multiple-person long-term space missions.

To this end, then, the psychological assessment program sought information about sensory functioning, perceptual and motor skills, group dynamics, and individual attitudes and experiences throughout the thirty days of the MESA mission. Many of the measures were included to establish similarities and differences of this experience with many similar studies of confinement. Others, notably the sensory functioning measures, were included in the program because they have rarely been measured before in such environments.



#### 6.4.2.2 METHOD

##### I. Subjects

The MESA test crew was composed of five men (ages 26, 26, 28, 33 and 36 years) two of whom were provided by NASA and three who were Boeing employees. One member was a physician currently serving as a Naval flight surgeon. Another had his M.A. degree and is studying for his Ph.D. Two other crew members were college graduates. The fifth, although not having formal education beyond high school, possessed considerable training of relevance to the MESA project. One subject had been a member of the crew during the aborted MESA I attempt.

##### II. Psychological Monitoring Schedule

At the beginning of the period of confinement, psychological monitors were assigned to man the communication and data collection center (the psychological monitor's station) twenty-four hours a day. Later in the run the schedule was reduced to the eight hours per day from 0800 to 1600 hours, seven days a week. Nearly all of the data to be reported here were thus collected during these hours. For this reason no attempt was made to evaluate performance as a function of time of day. (See Photo 28).

The psychological monitor was responsible for all communications pertaining to the collection of psychological data. Many of the tests were initiated and scored from his station. Others were self administered by the subjects and later passed through the air lock. One member of the crew inside the chamber assisted by handing out appropriate test forms at prescribed intervals.

##### III. Test Procedures and Schedules

###### A. Sensory Capabilities

###### 1. Visual

###### a. Phoria

Phoria was measured in a Keystone 41C Telebinocular (a stereoviewer with + 5 diopter split spherical lenses.) The subject viewed an arrow with his left eye and a numbered scale with his right. The relative positions in which he perceived the arrow and the scale provided a measure of the convergence relationship between his eyes at the particular accommodation setting used. Test materials were

constructed similar to those available commercially for clinical use with this instrument but with several ortho positions to reduce problems with memorization of responses. (See photo 30.)

Phoria was measured in the lateral axis at both near and far points (equivalent distances of 16 inches and infinity). Only far point phoria was measured in the vertical axis. Each test session involved three tests of each of the three phoria conditions. This task was originally scheduled for every three days; after Day 6 it was rescheduled for every four days. Testing before and after confinement was complete for all subjects.

b. Stereopsis (depth perception)

Stereopsis (depth perception) was measured in the same viewer as phoria. The stimulus material consisted of a set of "multi-stereo" test cards, obtained from the Keystone View Company, Meadville, Pennsylvania. They consisted of stereo photos of sets of eleven vertical rods mounted at different apparent distances from each other. The subject was required to record the nearer member of each adjacent pair of rods. For each test session a subject was asked to view five or more photos selected to bracket his threshold. He recorded his responses for these photos on a scoring sheet. Stereopsis was measured only at the far point.

This test was scheduled for every three days during the run. After Day 6 it was rescheduled for every four days; one of these test points (Day 13) was used instead for acuity. Testing before and after confinement was complete for all subjects.

c. Acuity of Resolution

Acuity was measured with the same viewer as phoria. Test material was the Wolf matrix of Landolt Cs in various sizes. These consisted of five by five matrices of black rings on a white background, each ring having a gap in one of four positions, up, down, left or right. Each test card held 2 identical matrices mounted for binocular viewing. The subject observed a card in the viewer at far point and responded with the orientation of the split in each ring.

Up to Day 7, subjects recorded their responses to preassigned cards on score sheets. After Day 7 subjects reported their responses verbally to the psychological monitor, who assigned them three cards, one at a time, on the basis of their prior performance.

All subjects were tested before and after confinement. Testing was scheduled for every three days during the run. On Day 7 (at which time only one subject had been tested) the schedule was reduced to two more sessions.

d. Critical Flicker Frequency (CFF)

The critical flicker frequency fusion point was measured with a specially designed system of fluorescent lamps. One lamp, controlled by a multivibrator, provided a flickering .75 inch target spot with a 50% duty cycle. A five inch background area surrounding the target was illuminated with fluorescent lamp of similar color. The frequency of the target was varied by a motor driven cam which reversed at randomly selected points. The subjects were instructed to respond by pressing a button each time it fused or began flickering. They were to make 12 such responses each session. (See photo 29.)

Subjects were tested through Day 6 at four background levels; from Day 6 on only the 30 foot lambert background level was used. Also, testing was cut from once every three days to once every four days. Actual background and target intensities were 24 and 55 (average) foot lamberts.

2. Auditory

a. Pitch Discrimination

In the pitch discrimination test, subjects listened to recorded series of tone pulses. The pulses were at a 60 db sound pressure level (re.0002 dynes/cm<sup>2</sup>) and averaged 950 cycles per second. Each pulse in a series was from zero to 14 cycles higher or lower in frequency than the previous one. The subject compared the pitch of each pulse with the pitch of the preceeding pulse and made a corresponding response on a score sheet. A test session included ten presentations of each of ten frequency differences.

Three subjects were tested prior to confinement; all subjects were tested afterwards. Background noise was quite high during the run, since all the equipment was functioning. It was lower before the run, when only the ventilating system was on and very low afterwards, when no equipment was on.

b. Intelligibility

Three tests of intelligibility were used. They consisted of verbal material played to the subject from tape recordings at a 60 db sound pressure level (re .0002 dynes/cm<sup>2</sup>), along with white noise at an equal level. Test 1 consisted of 50 common monosyllabic words. Test 2 consisted of 20 sentences with 100 key words. They were both taken from Beranek, Acoustic Measurements, Wiley, 1949. For both, subjects were required to write the recorded material as they heard it in the noise background. Test 3 consisted of 24 words, taken from WADC TR 52-223. Responses were made on score sheets containing 24 groups of four words. One word in each group was recorded; the other three were selected to sound similar to the correct word. Scoring was based on the number of words written (or circled) as they were pronounced.

Test 1 was given before confinement to three subjects. All three tests were originally scheduled to be given every three days during confinement. They were given once before Day 6 and, as rescheduled, twice after Day 6. In addition, they were given once to all subjects after confinement. No subject was tested with a particular form of the test more than once.

B. Performance Abilities

1. Tracking - This task required compensatory velocity tracking in two dimensions with a random noise input signal. Two minute trials alternated with 10 second rest periods. Performance was recorded as absolute error integrated over each two minute trial. On some days subjects performed on the tracking task only for 15 to 25 minutes. On alternate days, they performed on the tracking task by itself and then on tracking combined with monitoring. (See photo 31.)

All subjects except C, the replacement, received limited preconfinement testing. All subjects were tested after confinement. Testing during the run was originally scheduled for every three days. After day 6, it was rescheduled for approximately every four days.

Test sessions prior to Day 6 consisted of 12 to 24 minutes of tracking only, or five to ten minutes of tracking only followed by a 22 minute session of tracking with monitoring. Each sequence was scheduled every three days. After Day 6, sessions of tracking only were stabilized at 20 minutes, tracking before monitoring at six minutes, tracking with monitoring at 22 minutes, and the schedule was reduced to one repeat every four days.

## 2. Monitoring

The monitoring task consisted of four warning lights and four meters. The subject was required to turn off each indicator with the correct one of eight pushbuttons as rapidly as possible after it was illuminated (lights) or deflected from zero (meters). Each test session lasted 22 minutes and included 32 stimuli, four for each display in a random order. This task was always used in conjunction with tracking.

All subjects except C, the replacement, received one preconfinement test session and all subjects were tested after confinement. On Day 6, the monitoring test schedule was changed from once every three days to once every four days.

## 3. Time Estimation

For the 15 and 60 second time estimations, subjects held a pushbutton closed for the interval they estimated. All data up to day 6 were based on estimates made in the complex information processing (orbit correction) task. After this task was dropped, on Day 6, two estimates of each interval were scheduled every four days. For the 60 second interval, all subjects but C made prerun estimates. The orbit correction task did not include many corrections in the neighborhood of 15 seconds so the data prior to day 10 are limited.

All subjects were tested after the run.

Five minute time estimates were carried out by verbal contact between the psychological monitor and the subject. This task was missed in the pretest schedule so no pre-confinement data exist. Complete data were obtained during and after the run.

## C. Psychological Scaling of Experiences

1. Inventory I-A, I-B, and I-C. This was a retrospective questionnaire designed to evaluate various experiential factors during the MESA confinement. Most of the items used were drawn from a questionnaire developed by HUMRRO in Monterey, California for use in experimental studies

of isolation and confinement. The MESA questionnaire contained thirty factors such as: group annoyance, efficiency of thought, unusual visual and auditory experiences, restlessness, physical complaints, time tedium, lonesomeness or isolation, worry or fright, speech difficulties, and the like.

All two-hundred statements in the inventory were written so as to be applicable to life outside as well as inside the chamber. The subject placed a check mark beside each item beneath one of three columns to indicate how much the item applied to him during the specified time referent. His choices were: Never, Once or Occasionally, and Frequently. The inventory was given first several days prior to entry into confinement (Inventory I-A). On this occasion the subject was asked to check each item to indicate how often it would be likely to apply to his experiences during a typical week of his life. The second administration was on Day 7 (Inventory I-B), this time referring to experiences during the first week in the chamber. The third form of the questionnaire (Inventory I-C) was given at one week intervals thereafter (on Days 14, 21 and 28), with the instruction each time to fill it out with respect to the previous week. Instructions for the three forms of the test and the various test items are given in the MESA Test Plan (D2-90487-3).

2. Modified NRL Scales I and II. This rank order scale was drawn, with minor modifications, from Naval Research Laboratory Report 5882, a study dealing with two-week confinement in a fall-out shelter. It consisted of twenty-one potentially annoying or bothersome items which were to be placed in rank order in terms of: 1) "how much" and 2) "how often" they bothered the crew member during the specified time interval. The items are fully listed in the results section. The test was administered first as a pre-confinement prediction baseline (Scale I). In this test each subject was asked to make up his rank orders in terms of "how much" and "how often" he predicted the individual items such as behavior of others, noise, food, etc. would bother him during the thirty day chamber confinement. Scale II was administered four times during confinement (on Days 9, 16, 23, and 30). On each of these occasions the subject ~~rank~~-ordered the list to indicate how the items had bothered him during the previous week. Although not all specific situations which could be expected to bother personnel of the MESA study were represented on the list, the test was used to establish potential similarities with prior experiments.
3. Myers Scale A, B and C. The Myers scale is an adjective check list having as its primary aim the assessing of how

positively and how negatively a person rates his mood at any given time. The test used here is identical to that developed for use by HumRRO in Monterey, California for evaluating mood changes in studies of experimental isolation and confinement. The Myers Scale consists of 114 words, 62 of which were selected to have high social desirability. The remaining 52 words rate low on the social desirability dimension. The scale can be rapidly scored to give a positive and a negative mood factor. In the present study it was used to determine whether there were any gross mood changes throughout the thirty day confinement as compared with pre-confinement baselines. Myers Scale A was given pre-confinement with each subject checking each word to indicate how characteristic it was of him: 1) "Now", meaning at that moment, and 2) "Normally", meaning during a typical week of his life. His answer choices were: 1) Not at all characteristic, 2) Somewhat or slightly characteristic, or 3) Mostly or generally characteristic of him. The numbers 1, 2 and 3 were also used as the score values. Myers Scale B was given on Day 4 of the confinement experience. In addition to checking the scale for "Now" and "Normally" a third column was employed, "Then". "Then" referred to the first few days in the chamber. Myers Scale C was given at approximately one week intervals thereafter (on Days 11, 17, 25, and 31). The "Then" column of Myers Scale C always referred to the previous week in the chamber. See the MESA Test Plan (D2-90487-3) for further information about this test.

#### 4. Subjective Stress Scale (SSS).

The SSS is a psychologically-scaled list of words which have been judged to connote varying levels of stressfulness. It was developed by Kerle and Bialek (HumRRO, Monterey, California) as a means by which a person could indicate quantitatively how much stress he felt at a given moment. It has proven extremely useful in finding out how stressed subjects are in a variety of experimental situations when other measures are difficult to obtain. In order from least to most stress the list is: wonderful, fine, comfortable, steady, doesn't bother me, indifferent, timid, unsteady, nervous, worried, unsafe, frightened, terrible, in agony and scared stiff. The subject is asked to circle the word or phrase which best describes how he feels at a given moment. In the MESA experiment it was given seven times, always with the instruction to describe how the subject felt "Now" (at that moment). Several days prior to the beginning of confinement it was given to obtain a general baseline. It was also given just minutes prior to entering the chamber, to assess entry stress. During confinement it was given



on Days 2, 6, 13, 20, and 27. The calculated scale values associated with the chosen words were used for analysis purposes.

#### 5. Hostility Scale (H Scale).

The checklist for feelings of hostility was developed by Berkun et al (HumPRO, Monterey, California) for the measurement of hostility, anger or aggression. It is intended to aid in determining the amount of hostility aroused in persons by certain experiences. In limited use it has been capable of revealing greater hostility in subjects who have been subjected to conditions designed to lead to this feeling.

The H Scale, like the SSS, is a psychologically-scaled list of words connoting varying degrees of (in this case) hostility. In use here it required the subject to circle the word or phrase which best described how he felt about "MESA" or "the group" at certain points in time (now, when you first entered the chamber, and at the point when you felt least favorable toward it). From least to most hostile the rank order of the H Scale is: delighted with, pleased with, favorable about, didn't mind, indifferent toward, displeased with, offended at, cross with, fed up with, tee'd off at, hot under the collar about, burned up at, ready to blow my top at, boiling mad at and raging mad at. The H Scale was given before confinement to establish "Now" baselines. During confinement it was given weekly (Days 5, 12, 19 and 26). Again the assigned scale values for the chosen words were employed in analyses.

#### IV. Required Changes in the Psychological Testing Program

Throughout the project, MESA was viewed as primarily a life support system checkout. As such the behavioral test program, while constituting a considerable portion of the crew's work load, was generally considered to be of low priority. Such an attitude coupled as it was in two cases with an extremely negative attitude toward the psychological measurement program before confinement ever began, led to poor subject motivation. On Day 5 crew feelings about their heavy work load developed into a situation which was viewed as potentially leading to a crew abort of the experiment. In order to preserve the best possible chances for completing the thirty day system checkout, to restructure the poor test-taking motivations of crew members, and to lessen the apparently excessive work load, a considerable reduction in the psychological measurement program was undertaken on Day 6.

Twenty-four psychological tests were included in the original measurement program. Ten were removed on Day 6. Five of these were in the area of sensory capabilities, with three visual tests removed: color perception, differential brightness threshold and peripheral vision; as well as two auditory tests: absolute loudness threshold and differential loudness threshold. In the area of performance ability three tests were eliminated



from the program: vigilance, complex information processing and decision making. Finally from among the instruments sampling subjective experiences the Nowlis Adjective Check List and the adaptation of Osgood's Semantic Differential were also dropped. Several factors determined the program reduction choices. In general, however, apparatus difficulties, attitudes of the subjects about specific tests, and redundancy of measurement built into the program ended up being the most important explanations for choosing to eliminate the above ten tests. In addition to reducing from twenty-four to fourteen tests, nine of the remaining tests were given less frequently than originally planned.

### 6.4.2.3 RESULTS

#### I. Sensory capabilities

##### A. Visual

##### 1. Phoria

Figure 49 and Table 11 show the data obtained for near point lateral phoria. Exophoria (relative divergence) increased in the latter part of the run, dropping to prerun levels at the post test, only a few days after confinement. A treatments by subjects analysis of variance showed the changes over time to be significant. (Table 12 ,  $F=3.06$ ,  $df=5, 20$ ,  $P<.05$ ).

Tables 13 and 14 show the data for far point lateral and vertical phoria. No changes over time were evident and no statistical analyses were performed.

##### 2. Stereopsis (depth perception)

Threshold data (75%, or 50% better than chance) are given in Table 15. Subject B never performed better than chance. Subject D was tested several times during confinement but never performed better than chance. He did give a measurable threshold before confinement and afterwards with the viewer set .25 diopters closer than the +.25 diopter specified as standard for far point. Subject E consistently required the viewer at a nearer point to prevent blurring of the image. All scores obtained at these settings were corrected to actual visual angles.

Two subjects, A and E, were not always given an adequate range of stimulus material. As a result it was sometimes possible to report only that they could perform on material of a certain size or not on material of another size (e.g., a score of  $< 3.6$  meant that the subject performed better than threshold on material with a size 3.6 and that he was not tested with harder material). In all cases for stereopsis the direction of the inequality was to allow a further increase in a high score or a further reduction in a low one.

An analysis of variance was calculated for the three subjects, A, C and E, who provided regular threshold data. The scores for subject E were much larger so

they were divided by five to make them more comparable. The mean scores reported include these reduced values. Inequalities were included in the means and analysis without regard for sign. The analysis indicated no significant changes over time (Table 16 ,  $F=0.69$ ,  $df=5, 10$ ,  $P<.20$ ).

### 3. Acuity of Resolution

Table 17 shows subjects' 75% thresholds (67% better than chance) for visual acuity of resolution at far point. Data are in decimal equivalents, the inverse of the visual angle of the gaps in the split rings. Subject B normally required glasses for far vision but he did not use them in the chamber and he gave no meaningful thresholds during this period. Subject D reported the viewer had moved while testing on Day 30 and so his data for that day were lost. Testing from Day 13 on involved a different technique than was used earlier. Pretesting for three of the five subjects did not bracket their thresholds and so their results are reported as inequalities. MESA I data are reported for subject D for comparison purposes. Because of the difficulties noted above, no statistical analysis of the data was calculated.

Some limited generalizations may be made however. All subjects improved on the post test. Subject A, the only one for whom adequate pretest and during-test thresholds were obtained, showed very stable performance while confined. Subject D, who reported considerable eye fatigue during the run, gave a threshold on Day 13 which was much lower than his post test and his apparent pretest level. He reported on Day 13 that he was unable to distinguish any of the test material at the far point so he moved it .75 diopter closer. Subject E showed improvement continuously from Day 6.

### 4. Critical Flicker Frequency (CFF)

Table 18 and Figure 50 show the CFF fusion points obtained. Two analyses of variance were calculated for these data. The first (Table 19 ) shows that the change in performance from Day 3 through the post test was significant ( $F=4.59$ ,  $df=4, 16$ ,  $P<.05$ ). The second (Table 20 ) excluded the post test data, which showed a drop in performance. The remaining consistent improvement in performance throughout the run was significant ( $F=5.61$ ,  $df=3, 12$ ,  $P<.05$ ). The pretest data excluded from the analyses showed no consistent trends.

TABLE 11  
NEAR POINT LATERAL PHORIA IN DIOPTERS\*

SUBJECT	DAY OF RUN					POST
	PRE	8,9	19,20	23,25	29,30	
A	+5.1	-5.4	+2.0	+5.1	+6.4	-2.0
B	+15.4	+16.9	+22.0	+31.8	+34.1	+20.0
C	+4.1	+5.6	+5.1	+5.1	+5.4	+3.1
D	+8.7	+10.2	+9.2	+13.8	+11.3	+9.7
E	+8.7	+7.7	+8.7	+9.7	+10.0	+8.2
MEAN	+8.4	+7.0	+9.4	+13.1	+13.4	+7.8

\* Exophoria (relative divergence) is plus

TABLE 12  
ANALYSIS OF VARIANCE OF NEAR POINT LATERAL PHORIA  
FOR PRETEST THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	5	38.0	3.06	<.05
SUBJECTS	4	410.4	33.10	<.01
DAYS x SUBJECTS	20	12.4		
TOTAL	29			

TABLE 13  
FAR POINT LATERAL PHORIA IN DIOPTERS\*

SUBJECT	DAY OF RUN					POST
	PRE	8,9	19,20	23,25	29,30	
A	+1.2	+1.0	-2.0	0	+1.3	+1.7
B	+8.0	+8.3	+10.0	+11.0	+10.0	+10.7
C	+.5	+3.0	+1.0	+1.0	+1.5	0
D	+4.7	+4.7	+4.0	+3.7	+4.0	+4.0
E	-2.2	-1.0	+2.0	0	0	-2.0
MEAN	+2.4	+3.2	+3.0	+3.1	+3.4	+2.9

\*Exophoria (relative divergence) is plus

TABLE 14  
FAR POINT VERTICAL PHORIA IN DIOPTERS

SUBJECT	DAY OF RUN					POST
	PRE	8,9	19,20	23,25	29,30	
A	-.44	-.50		-.65	-.37	-.35
B	-.57	-.35		-.09	-.26	-.40
C	-.43	-.37	-.38	-.48	-.38	-.54
D	+.15	+.60		-.60	-.32	-.52
E	-.34	-.33		-.42	-.38	-.48
MEAN	-.33	-.19		-.45	-.34	-.46

TABLE 15  
75% THRESHOLD FOR  
STEREOPSIS (DEPTH PERCEPTION)  
IN SECONDS OF ARC

SUBJECT	DAY OF RUN						POST
	PRE	4	8.9	19,21	23,25	29,30	
A	6.4		<3.6	4.5	<1.1	4.5	5.5
B							
C	1.8	6.1	3.6	6.3	7.2	7.2	4.5
D	12.9						12.5 (.50)
E	16.3 (1.25)	15.3 (1.50)	17.5 (1.50)	>42.9 (1.50)	>46.7 (1.50)	<22.4 (1.25)	<17.8 (1.25)
MEAN*	3.8		3.6	6.5	5.9	5.4	4.5

( ) = Accommodation setting in diopters; far point is .25  
\* Mean for subjects A, C and E (see text)

TABLE 16  
ANALYSIS OF VARIANCE OF 75% STEREOPSIS  
THRESHOLD FOR PRETEST THROUGH POST  
TESTS, SUBJECTS A, C, E

SOURCE	df	MS	F	P
DAYS	5	4.01	.69	NS
SUBJECTS	2	2.27	.39	NS
DAYS x SUBJECTS	10	5.79		
TOTAL	17			

TABLE 17  
75% THRESHOLD FOR VISUAL ACUITY  
OF RESOLUTION AT FAR POINT IN  
DECIMAL EQUIVALENTS

DAY OF RUN

SUBJECT	MESA I					
	PRETEST	PRE	6,7	13	30	POST
A		2.01		2.01	2.01	2.10
B		1.90				1.98
C		<1.90		1.84	1.80	1.98
D	1.66	<1.70		1.25 (1.00)		1.69
E		> .88 (1.50)	.98 (1.25)	1.13 (1.25)	1.22 (1.25)	1.54 (1.25)

( ) = Accommodation setting in diopters; far point is .25

TABLE 18  
CFF FUSION POINT IN CYCLES PER SECOND

SUBJECT	DAY OF RUN						POST
	PRE	3,5	11	15,16	25,26	29,30	
A	40.3	39.1		39.1	40.6	40.1	40.1
B	38.0	37.6		37.4	38.4	38.6	37.8
C		39.6		39.8	39.9	40.9	39.2
D	34.7	38.4	41.7	42.0	41.8	43.1	40.5
E	38.4	35.8	39.9	40.0	39.2	39.1	38.9
MEAN		38.1		39.7	40.0	40.4	39.3

TABLE 19  
ANALYSIS OF VARIANCE OF CFF FUSION POINT  
FOR DAY 3 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	4	3.72	4.59	<.05
SUBJECTS	4	7.70	9.51	<.01
DAYS x SUBJECTS	16	.81		
TOTAL	24			



TABLE 20  
ANALYSIS OF VARIANCE OF CFF FUSION POINT  
FOR DAY 3 THROUGH DAY 30

SOURCE	df	MS	F	P
DAYS	3	5.17	5.61	<.025
SUBJECTS	4	6.88	7.48	<.01
DAYS x SUBJECTS	12	0.92		
TOTAL	19			

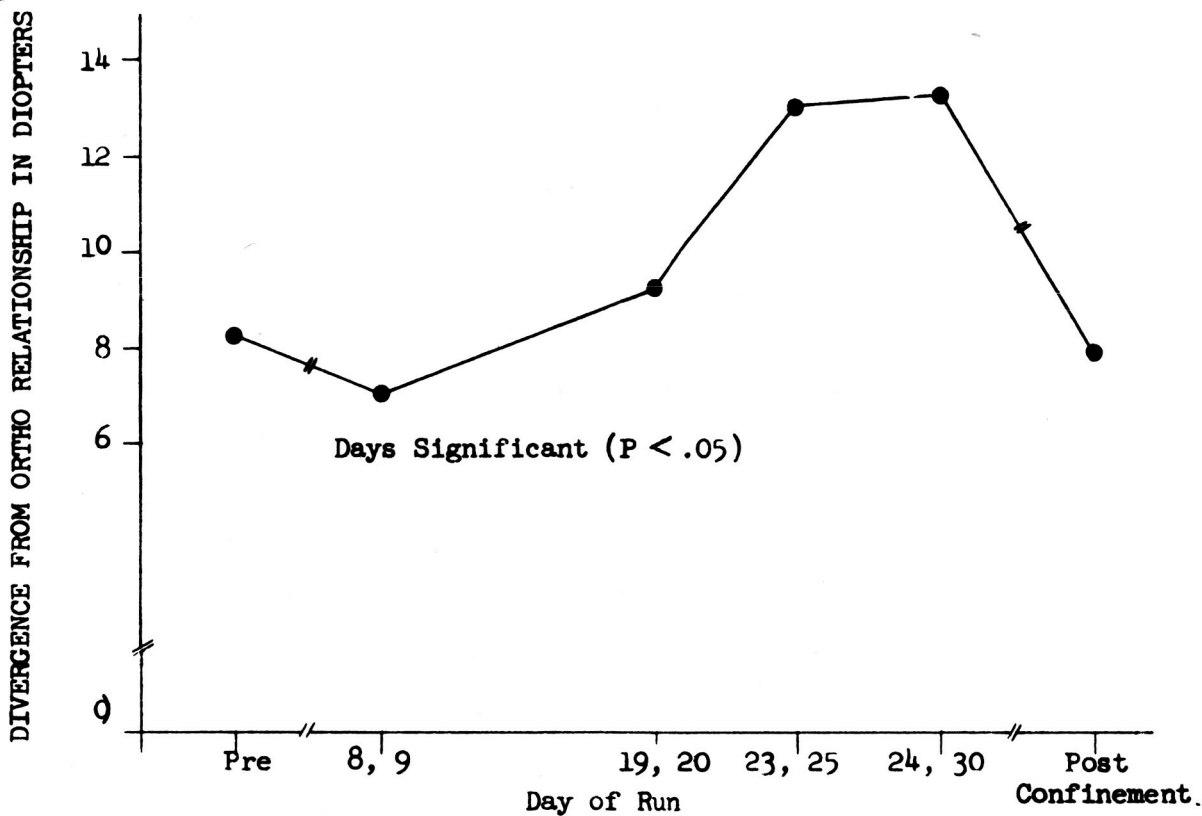


FIG. 49. NEAR POINT PHORIA AS A FUNCTION OF TIME IN CHAMBER

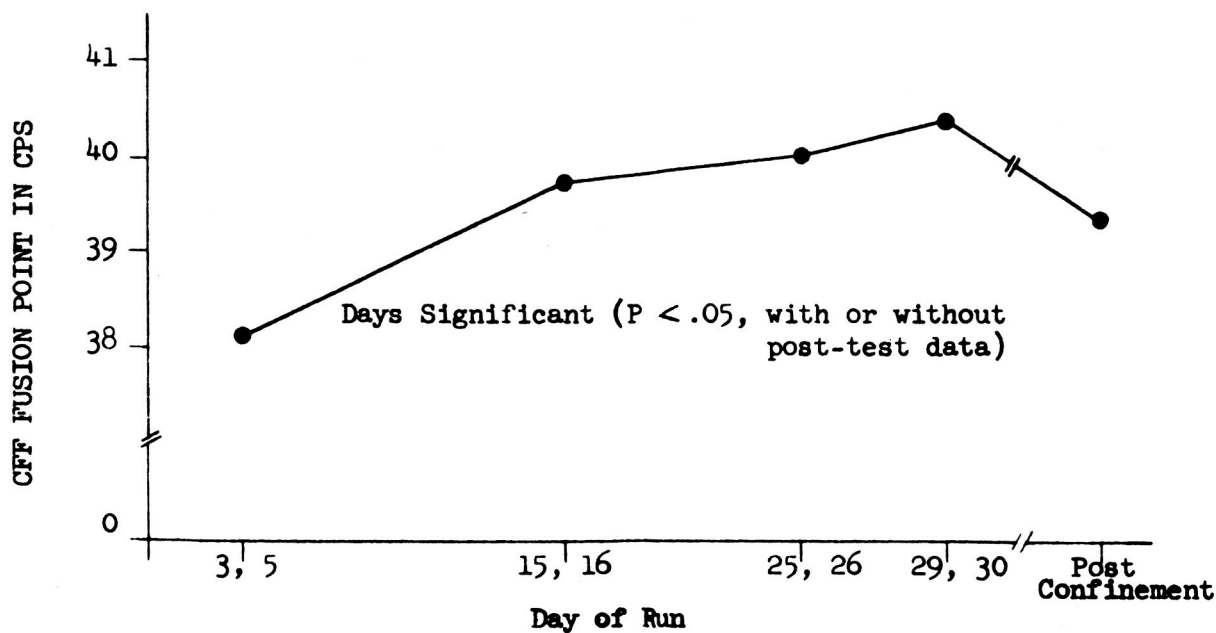


FIG. 50. CFF FUSION POINT AS A FUNCTION OF TIME IN THE CHAMBER

## B. Auditory

### 1. Pitch Discrimination

A white noise source, also at approximately 60 db, was inadvertently turned on while four of the subjects were being tested after the run. It may also have been on occasionally during the run. Inspection of post test data for those subjects who received the noise suggested that there was no decrement in performance attributable to the noise. However, the uncertainty on this issue makes all of the pitch discrimination data questionable.

Thresholds were obtained for each session by plotting the percentage correct at each frequency difference, followed by manual curve fitting. Table 21 shows the 75% -correct (50% better than chance) thresholds obtained. The pretest score for subject B is from MESA I pretest results.

There was a large increment in average performance level on Days 27-29, as compared with earlier and later scores. However, an analysis of variance calculated for the last three test sessions indicated no significant changes over time (Table 22 ,  $F=2.09$ ,  $df=2, 8$ ,  $P<.20$ ).

### 2. Intelligibility

Tables 23 and 24 give percent correct scores for tests 1 and 2. The pretest data for subject D is from MESA I. Figure 51 shows mean performance levels for tests 1 and 2 for those days on which data was complete. A decrement in performance on both tests was evident for Day 28. Differences over time were significant for both tests (Tables 25 and 26 ,  $F=4.66$  and  $4.54$ ,  $df=3, 12$ ,  $F<.025$ ). The pretest data excluded from the analysis show improvement by all subjects.

The changes noted above on test 2 were partially the result of subjects not writing as rapidly as the material was presented. The test was quite difficult in this respect and several subjects skipped portions of the material, especially on Day 28. Table 27 shows the number of words actually recorded incorrectly by each subject, including the proportion of words that were estimated to have been skipped because they were not heard adequately. On the basis of these scores there was no suggestion of any decrement in performance on test 2 for Day 28.

Subjects experienced some difficulty with scoring procedures for test 3. As with test 2, words were sometimes skipped. The actual percentage of correct responses are shown in Table 28. No statistical analysis was considered justified.

TABLE 21  
75 % THRESHOLD FOR PITCH DISCRIMINATION  
IN CYCLES PER SECOND

SUBJECT	DAY OF RUN				
	PRE	3	16	27,29	POST
A	4.0	1.6	2.9	2.6	1.6
B	5.4	3.6	3.0	2.0	6.3
C		3.8	1.6	1.9	2.0
D	5.2*	5.0	4.8	4.0	5.6
E	4.4		4.2	1.2	4.0
MEAN			3.3	2.3	3.9

\*MESA I PRETEST DATA

TABLE 22  
ANALYSIS OF VARIANCE OF 75% THRESHOLD  
FOR PITCH DISCRIMINATION FOR  
DAY 16 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	2	3.10	2.09	<.20
SUBJECTS	4	4.08	2.76	<.20
DAYS x SUBJECTS	8	1.48		
TOTAL	14			

TABLE 23  
PERCENT CORRECT FOR INTELLIGIBILITY TEST 1

SUBJECT	DAY OF RUN					POST
	PRE	PRE	3,5	18,19,23,	28	
A	44	52	62	68	36	62
B	54	58	72	70	56	60
C			74	72	56	74
D	52*	58*	64	48	54	66
E	50	40	60	56	56	64
MEAN			66	62	52	66

\*MESA I Scores

TABLE 24  
PERCENT CORRECT FOR INTELLIGIBILITY TEST 2

SUBJECT	DAY OF RUN			
	3,5	18,19,23	28	POST
A	79	80	45	80
B	90	95	78	88
C	85	94	84	84
D	65	52	36	83
E	87	80	64	69
MEAN	81	80	61	81

TABLE 25

ANALYSIS OF VARIANCE OF PERCENT CORRECT FOR  
INTELLIGIBILITY TEST 1 FOR  
DAY 3 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	3	229.2	4.66	<.025
SUBJECTS	4	104.0	2.11	<.20
DAYS x SUBJECTS	12	49.2		
TOTAL	19			

TABLE 26

ANALYSIS OF VARIANCE OF PERCENT CORRECT FOR  
INTELLIGIBILITY TEST 2 FOR  
DAY 3 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	3	468	4.54	<.025
SUBJECTS	4	569	5.52	<.01
DAYS x SUBJECTS	12	103		
TOTAL	19			

TABLE 27  
PERCENTAGE INCORRECT AND SKIPPED OR INCORRECT FOR  
INTELLIGIBILITY TEST 2

SUBJECT	DAY OF RUN			
	3,5	18,19,23	28	POST
A	10	9	15	13
B	10	5	10	10
C	12	6	13	14
D	7	12	13	14
E	13	18	11	17
MEAN	10	10	12	14

TABLE 28  
PERCENT CORRECT FOR INTELLIGIBILITY TEST 3

SUBJECT	DAY OF RUN			
	3,5	18,19,23	28	POST
A		92	42	71
B	12	88	66	83
C	71	79	46	75
D	58	58	75	71
E		42	54	71
MEAN		72	57	74



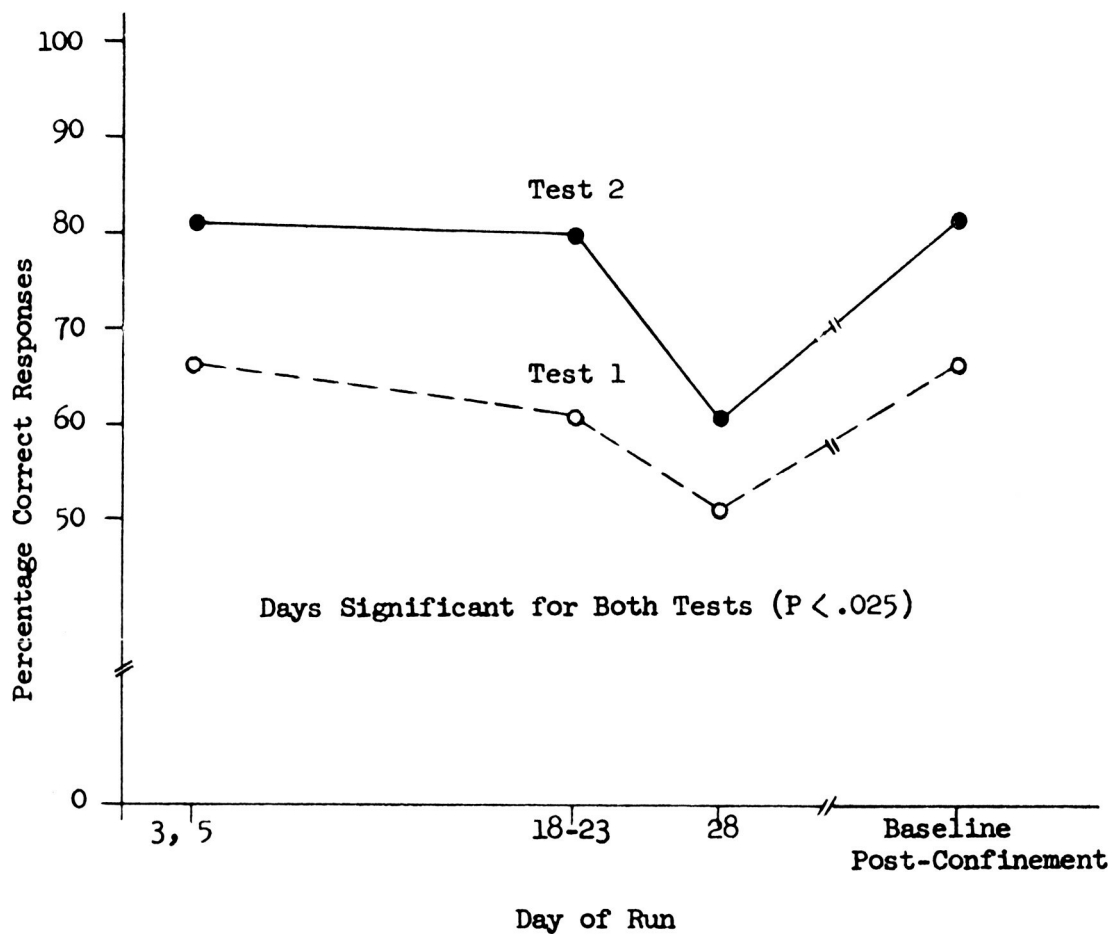


FIGURE 51  
PERCENTAGE CORRECT RESPONSES TO ITEMS OF THE INTELLIGIBILITY TESTS  
AS A FUNCTION OF TIME IN THE CHAMBER

## II. Performance Abilities

### A. Tracking

Subjects occasionally lost control of the target while tracking, even when highly practiced. On some occasions, this was known to have been caused by interruptions by other personnel. In most cases records were inadequate to determine the cause of the loss. To prevent undue distortion of the results, all trials during which the target was lost were excluded from the analyses.

Integrated error scores for the vertical and horizontal axes were recorded separately. For analysis purposes these scores were weighted appropriately to correct for average differences in level and were combined into a single score.

Comparison of integrated error scores on tracking alone and tracking before monitoring revealed no apparent differences in average level or trend so these scores were combined into a single score for each subject for each time period. Integrated error scores for tracking without monitoring are shown in Figure 52 and in Table 29. Tables 30 and 31 show the analyses of variance calculated for these data. Time in the chamber was significant both with ( $F=8.53$ ,  $df=4, 16$ ,  $P<.01$ ) and without ( $F=4.18$ ,  $df=3, 12$ ,  $P<.05$ ) days 2-6 included in the analysis, with the change in the direction of improvement over time. Pretest scores were not included in the analyses because of incomplete data. Inspection of Table 29 shows no consistent change from preconfinement to confinement.

Integrated error scores for tracking with monitoring are shown in Figure 52 and Table 32. Inspection of Figure 52 and the data in Table 32, including that excluded from statistical analysis because of empty cells, indicates a general tendency for improvement over time. However, the analysis of variance for these data only approaches statistical significance (Table 33,  $F=2.92$ ,  $df=3, 12$ ,  $P<.10$ ).

### B. Monitoring

At several points during the run the monitoring task malfunctioned and caused the stimulus to remain on after the subject had responded. The score used for each of these trials was the interval of time from the onset of the stimulus until a response was made.

Comparison of the few scores made under these conditions with other scores made during the same test session yielded no detectable differences so they were included in the analysis.

Response latencies on the warning light task are shown in Figure 53 . Table 34 shows response latencies for each subject and time period. Most of the cells from days 2 through 29 represent two days of testing. Tables 35 and 36 show the analyses of variance calculated for these data. The first analysis indicated significant improvement over time ( $P < .025$ ). The second analysis excluded days 2 to 6 and showed no significant changes over time.

Response latencies for the meter portion of the monitoring task are shown in Table 37 . Comparison of average latencies appears to show large changes over time, with the best performance at days 9 to 14 and again after the run. However, there was no significant change in performance over time (Table 38 ,  $F = 1.74$ ,  $df = 4, 16$ ,  $P < .20$ ). Comparison of individual scores in Table 37 shows large individual differences in performance trends, with subject D worst on days 9-14 and most of the loss on days 17 to 29 contributed by B.

Table 39 shows the average number of response errors per session for the monitoring task. The improvement over time was significant (Table 40 ,  $F = 3.71$ ,  $df = 4, 16$ ,  $P < .05$ ).

#### C. Time Estimation

Error ratios (judgement minus standard divided by standard) for the estimates made by each subject for each of the three intervals are shown in Tables 41 , 42, and 43. With a few exceptions each of the values after day 6 represents the mean of the four estimates for those days.

Of the three sets of time estimation data, that for the 60 second interval showed the most consistent tendency over time. An analysis of variance calculated for these data (Table 44 ) showed no significant changes as a function of period of confinement ( $F = 2.10$ ,  $df = 5, 15$ ,  $P < .20$ ). Since the other two sets of data showed even less consistent trends, no analyses of them were made.

TABLE 29  
AVERAGE INTEGRATED ERROR FOR TRACKING WITHOUT  
MONITORING

SUBJECT	DAY OF RUN					POST
	PRE	2-6	9-14	17-22	24-29	
A	74	114	72	41	41	41
B	165	186	89	68	85	47
C		86	44	26	32	21
D	74	84	68	23	18	22
E	86	36	32	24	35	48
MEAN		101	61	36	42	36

TABLE 30

ANALYSIS OF VARIANCE OF INTEGRATED ERROR FOR  
TRACKING WITHOUT MONITORING FOR  
DAY 2 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	4	3810	8.53	<.01
SUBJECTS	4	2955	6.62	<.01
DAYS x SUBJECTS	16	446		
TOTAL	24			

TABLE 31

ANALYSIS OF VARIANCE OF INTEGRATED ERROR FOR  
TRACKING WITHOUT MONITORING FOR  
DAY 9 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	3	695	4.18	<.05
SUBJECTS	4	1208	7.26	<.01
DAYS x SUBJECTS	12	166		
TOTAL	19			

TABLE 32  
INTEGRATED ERROR FOR TRACKING WITH MONITORING

SUBJECT	DAY OF RUN					POST
	PRE	2-6	9-14	17-22	24-29	
A	147		93	82	63	80
B	181	258	133	118	89	71
C		118	70	48	58	56
D	170	104	96	73	74	42
E	99	117	45	42	56	52
MEAN			87	73	68	60

TABLE 33  
ANALYSIS OF VARIANCE OF INTEGRATED ERROR FOR  
TRACKING WITH MONITORING FOR DAY 9  
THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	3	655	2.92	<.10
SUBJECTS	4	1739	7.76	<.01
DAYS x SUBJECTS	12	224		
TOTAL	19			

TABLE 34  
AVERAGE RESPONSE LATENCY FOR WARNING LIGHT  
MONITORING

SUBJECT	DAY OF RUN					POST
	PRE	2-6	9-14	17-22	24-29	
A	1.72	3.50	2.70	3.10	2.31	2.31
B	2.31	3.74	2.64	2.06	2.13	1.84
C		2.45	2.08	1.92	2.08	1.77
D	1.88	1.86	1.89	1.88	1.78	1.47
E	1.87	3.17	2.36	2.77	2.90	3.14
MEAN		2.94	2.34	2.34	2.24	2.10

TABLE 35  
ANALYSIS OF VARIANCE OF RESPONSE LATENCY FOR  
WARNING LIGHT MONITORING FOR  
DAY 2 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	4	.52	3.89	< .025
SUBJECTS	4	1.10	8.24	< .01
DAYS x SUBJECTS	16	.13		
TOTAL	24			

TABLE 36  
ANALYSIS OF VARIANCE OF RESPONSE LATENCY FOR  
WARNING LIGHT MONITORING FOR  
DAY 9 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	3	.062	.68	N.S.
SUBJECTS	4	.754	8.30	< .01
DAYS x SUBJECTS	12	.091		
TOTAL	19			

TABLE 37  
AVERAGE RESPONSE LATENCY FOR METER MONITORING

SUBJECT	DAY OF RUN					POST
	PRE	2-6	9-14	17-22	24-29	
A	7.6	8.9	6.2	7.4	7.1	8.3
B	9.2	7.3	6.1	9.3	10.6	5.8
C		7.4	5.5	5.6	6.2	3.9
D	5.7	5.0	8.0	6.0	6.4	3.6
E	5.8	9.2	7.0	6.8	7.0	6.2
MEAN		7.56	6.55	7.04	7.48	5.56



TABLE 38  
ANALYSIS OF VARIANCE OF RESPONSE LATENCY FOR  
METER MONITORING FOR  
DAY 2 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	4	3.40	1.74	< .20
SUBJECTS	4	5.04	2.57	< .10
DAYS x SUBJECTS	16	1.96		
TOTAL	24			

TABLE 39  
AVERAGE NUMBER OF MONITORING RESPONSE ERRORS  
PER SESSION

SUBJECT	DAY OF RUN					
	PRE	2-6	9-14	17-22	24-29	POST
A	1	1	0	1.5	.5	1
B	0	2	3	.5	.5	0
C		4.5	4	1.5	.5	1
D	2	1.25	0	0	1	0
E	5.5	2	4.5	2.5	1	1
MEAN		2.15	2.30	1.50	.70	.60

TABLE 40

ANALYSIS OF VARIANCE OF AVERAGE NUMBER OF MONITORING  
RESPONSE ERRORS PER SESSION FOR  
DAY 2 THROUGH POST TEST

SOURCE	df	MS	F	P
DAYS	4	3.78	3.71	<.05
SUBJECTS	4	3.97	3.90	<.025
DAYS x SUBJECTS	16	1.02		
TOTAL	24			

TABLE 41

ERROR RATIOS FOR 15 SECOND TIME ESTIMATION

SUBJECT	DAY OF RUN					
	PRE	2-6	11-16	19-23	26-31	POST
A		-.17	-.06	+.08	+.14	+.34
B		-.20	+.16	+.44	-.18	+.42
C		+.96	+.40	+.54	0	+.24
D			+.22	-.06	+.01	-.02
E	-.46		+.25	+.30	+.08	+.02
MEAN			+.20	+.26	+.01	+.20

TABLE 42  
ERROR RATIOS FOR 60 SECOND TIME ESTIMATION

SUBJECT	DAY OF RUN					POST
	PRE	2-6	11-16	19-23	26-31	
A	-.42	-.42	-.48	-.28	-.34	-.39
B	-.29	-.21	-.17	+.11	+.36	+.30
C		+.47	0	+.39	+.09	-.10
D	-.54	+.06	-.02	+.04	+.12	-.08
E	-.22	-.08	+.32	+.07	-.09	-.01
MEAN		-.04	-.07	+.07	+.03	-.06

TABLE 43  
ERROR RATIOS FOR 5 MINUTE TIME ESTIMATION

	DAY OF RUN				
SUBJECT	2-6	11-16	19-23	26-31	POST
A	+.29	+.22	+.44	+.74	+.71
B	+.22	-.02	+.38	+.41	+.40
C	+.17	+.40	+.34	+.42	+.54
D	-.06	+.43	+.04	+.10	+.07
E	-.22	+.01	-.06	+.20	+.12
MEAN	+.08	+.21	+.23	+.37	+.37

TABLE 44

ANALYSIS OF VARIANCE OF ERROR RATIOS FOR 60 SECOND  
TIME ESTIMATION FOR PRETEST THROUGH POST TEST  
EXCLUDING SUBJECT C

SOURCE	df	MS	F	P
DAYS	5	737	2.10	<.20
SUBJECTS	3	2068	5.88	<.01
DAYS x SUBJECTS	15	352		
TOTAL				

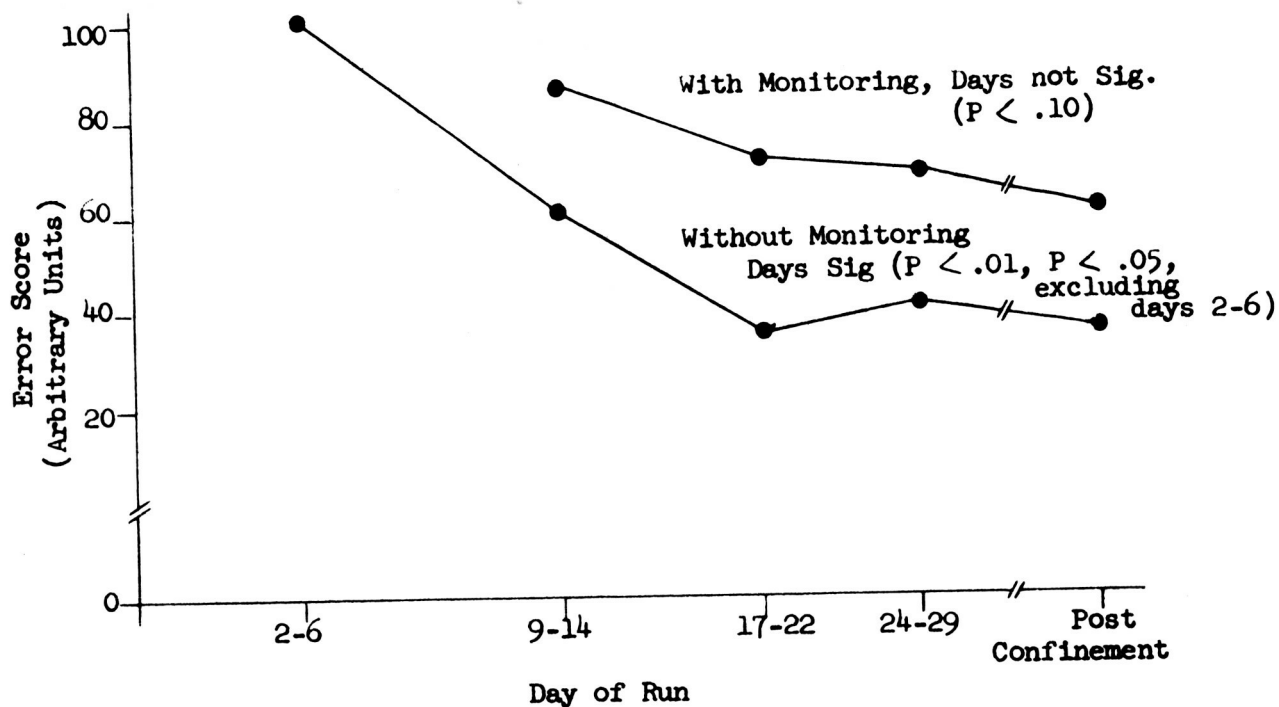


FIG. 52. INTEGRATED TRACKING ERROR AS A FUNCTION OF TIME IN THE CHAMBER

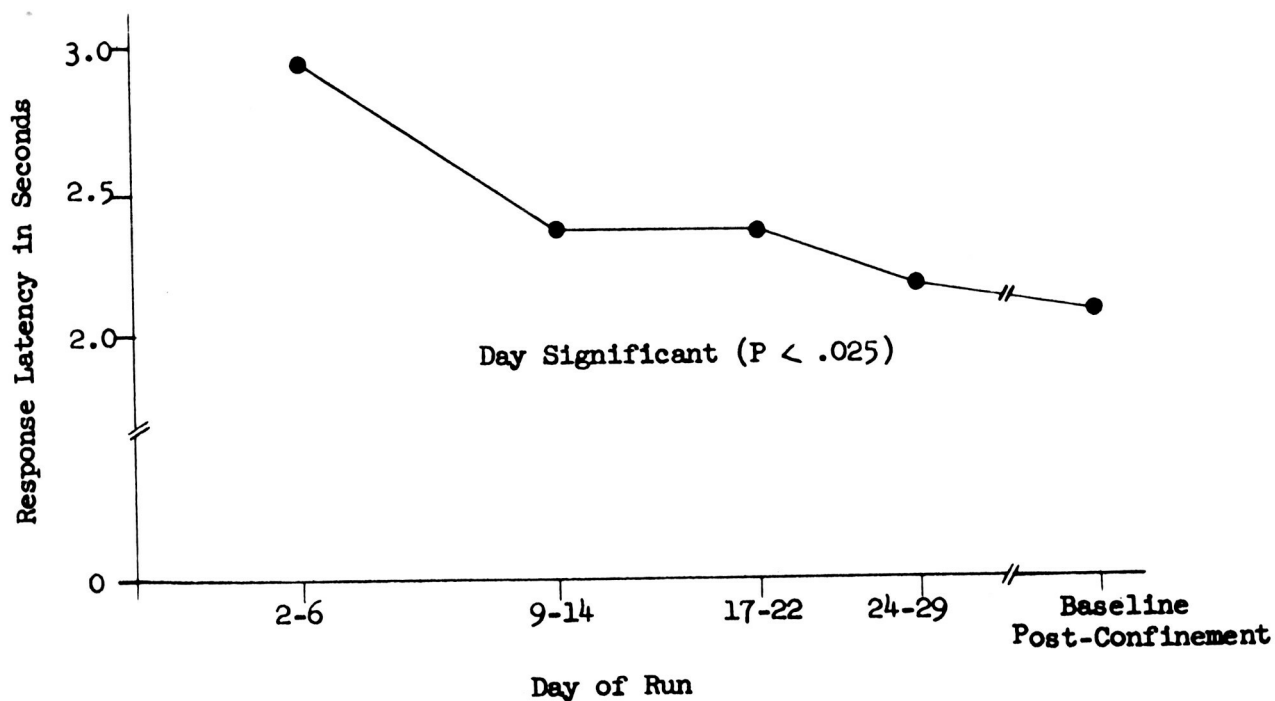


FIG. 53. RESPONSE LATENCY ON THE WARNING LIGHT TASK AS A FUNCTION OF TIME IN THE CHAMBER

### III. Psychological Scaling of Experiences

Five "paper and pencil" tests were employed to obtain data on subjects' moods, feelings, stress, and general experiences throughout the project. These were subjective, usually retrospective, data gathered to try to measure what it was like to be confined for a thirty day period in the MESA chamber.

#### A. Inventory 1-A, 1-B and 1-C.

The thirty factors of the confinement inventory were checked to see whether significant shifts occurred in the way in which the test crew marked the items comprising each factor during the run (Day 28) as compared with the pre-confinement baseline. In only five of the factors were there changes worthy of note.

A sizeable increase in "group annoyance" occurred during the run, apparently increasing with time ( $t=6.00$ ,  $df=4$ ,  $P<.01$ ). On Day 28 all five members of the crew indicated that the group annoyance items applied to them more than had been the case during the pre-confinement training period. Examples of such items are: "Little things which members of the chamber group did bothered me.", "One or more members of the chamber group got on my nerves.", "The other members of the chamber group generally annoyed me.", and "I got upset when I thought about how some of the chamber group members acted."

The more general factors of "well being" and "positive feelings" were reduced during the confinement experience ( $t=2.99$ ,  $df=4$ ,  $P<.05$  and  $t=2.70$ ,  $df=4$ ,  $P<.06$  respectively). The subjects generally felt less happy, comfortable and satisfied during the confinement. Examples of such items are: "I felt the world was a pretty nice place to be in.", "I found something entertaining to do.", and "I felt unusually happy."

The "time tedium" factor significantly increased ( $t=3.21$ ,  $df=4$ ,  $P<.05$ ) indicating that slow passage of time was an annoyance. Examples of "time tedium" items are: "Time seemed to pass very slowly." and "Time seemed to stand still."

Another factor which might be labeled "attitude toward the psychological experimenters" cannot be shown to have changed significantly for the entire crew due to highly negative attitudes for two of the five prior to the run. However, a sizeable negative shift occurred for the remaining three during the run. Such items as "I thought the psychological experimenters were wasting their time." and "I disliked thinking about the tests the psychological monitor gave me.", are examples.

From a confinement point of view it would be noteworthy to point out factors which showed no changes from baseline to

during-confinement. In the general area of intellectual efficiency no decrements were observed in such factors as "speech difficulty", "reminiscence and memory", and "inefficiencies of thought." Similarly, there did not appear to be any strange or unusual experiences connected with confinement, as evidenced by no changes in such factors as: "reported visual and auditory sensations", "dreams", "novelty and surprise", "reality", "worry and fright", and "body image." Other areas showing no change were: "sex", "religion", "lonesomeness", "fidgeting", "restlessness", "general anger and hostility", and "physical symptoms".

#### B. Modified NRL Scales I and II.

The mean ranks assigned to each of the 21 items on the NRL scale in terms of "how much" and "how often" each bothered the MESA crew members throughout the experiment are shown in Tables 45 and 46. Items are arranged in order of increasing annoyance during the confinement period. Taking the entire thirty day confinement into account the things which bothered the crew the "Most" were (in rank order): food, behavior of others, noise, toilet facilities, crowding of the chamber, worries about the outside and boredom. Note that on Day 30 these same seven items were at the top of the list but behavior of others, crowding of the chamber, worries about the outside and boredom had all increased in their annoyance relative to the other items. Examination of the same list of 21 items in terms of "How Often" they bothered the crew revealed generally the same items in the upper third. In rank order the items which most often bothered the crew throughout the full 30 days were: food, noise, toilet facilities, behavior of others, crowding of the chamber, boredom and lack of privacy. By Day 30, behavior of others and boredom were at the head of the list.

Overall it appears that certain test conditions (food, noise level, toilet facilities, etc.), personal interactions (both within the crew and between the crew and outside personnel) and boredom were frequent and often pronounced annoyances for the test subjects.

#### C. Myers Scale A, B and C.

The 114 adjectives in this check list were scored to indicate to what extent subjects checked "positive" and "negative" words as applying to them. Subjects filled out the check list to refer to three different times: 1) At the point of taking the test (Now), 2) During the week just passed (Then), and 3) During a typical or normal week of their lives (Normally). The results throughout the confinement for the "positive" factor to reflect mood "Now" are presented in Figure 54. A treatments by subjects analysis of variance of these data (summarized in Table 47) revealed a significant decline throughout the run in

the checking of positive words ( $F=4.05$ ,  $df=4, 16$ ,  $P<.025$ ). That is, subjects were less likely later in the run to check such words as overjoyed, content, sociable, enthusiastic, and calm as being highly applicable to their mood. No change was observed over time for the "negative" factor under the "Now" condition. The analysis of these data is summarized in Table 48 .

The category "Then" was used only during the confinement period. Referring to the entire preceding week, it was a more gross statement of retrospective mood. The analysis of the "positive" factor (Summarized in Table 49) revealed that the apparent decline in positive mood over time failed to reach statistical significance with this small number of subjects ( $F=3.12$ ,  $df=3, 12$ ,  $P<.10$ ). This result is depicted in Figure 55. The "negative" factor for the "Then" administration of the adjective check list again showed no changes over time (See Table 50 for the analysis of variance of these data).

Another form of baseline measure was provided by asking subjects to check the words in the list to indicate how they would "Normally" apply during a typical week of their lives. Both the "positive" and the "negative" factors significantly dropped throughout the run ( $F=3.78$ ,  $df=4, 16$ ,  $P<.025$  and  $F=3.34$ ,  $df=4, 16$ ,  $P<.05$  respectively). These results are graphically presented in Figures 56 and 57 and summaries of the analyses of variance are given in Tables 51 and 52 .

#### D. The Subjective Stress Scale (SSS).

The SSS values for the five subjects were analyzed to determine whether there were differences in psychological stress throughout the confinement as compared with baseline measures. An analysis of variance (summarized in Table 53 ) revealed no significant changes in stress among the various time points sampled ( $F=1.59$ ,  $df=6, 24$ ,  $P<.20$ ). High variability of the responses of the few respondents contributed heavily to this finding but it is worth noting that the amount of stress implied by even the most deviant points on the scale selected (Unsteady and Nervous) would not be viewed as particularly large.

#### E. The Hostility Scale (H Scale). The H Scale was used to collect information about potential changes in hostility feelings directed toward the other members of the chamber crew and toward the MESA project in general. In the case of how subjects felt "about the group at the point when--(they) -- felt the least favorably toward it." there was a highly significant decline, primarily from pre to during confinement ( $F=63.71$ , $df=3, 12$ , $P<.01$ ). These data are shown in Figure 58 and the analysis of variance is summarized in Table 54. The negative feelings toward the group were highest at the point of the last administration on Day 26 when four of the five crew members selected answers ranging from "Displeased with" to "Fed up with".



No other administrations of the H Scale revealed any changes over time, but at some points in the confinement four of the five subjects indicated displeasure with "MESA" when asked to check the scale to reflect how they felt at the time of their worst experience while in the chamber.

TABLE 45

Mean Ranks Assigned to the Items on the Modified NRL Scale to Indicate  
"How Much" They Bothered the Test Crew

Rank	Scale Item	DAY OF RUN				
		Pre	9	16	23	30
1	Food	6.8	1.2	8.2	5.4	6.6
2	Behavior of others	6.6	9.0	5.6	6.2	5.2
3	Noise	4.8	6.5	4.8	8.8	7.8
4	Toilet facilities	7.0	5.2	7.2	10.0	8.6
5	Crowding of the chamber	10.8	9.2	11.0	6.8	7.2
6	Worries about the outside	13.6	12.0	10.2	8.2	6.8
7	Boredom	10.0	15.0	9.4	7.2	7.2
8	Lack of water for washing	6.0	10.2	11.6	9.0	9.2
9	Trouble sleeping	13.4	8.5	9.4	13.0	11.4
10	Dirt	12.2	13.2	11.0	11.0	10.6
11	Lack of privacy	9.2	12.5	10.8	10.8	11.8
12	Bunks	16.6	9.0	13.6	10.6	13.6
13	Physical symptoms	14.6	16.8	9.6	9.4	11.6
14	Not able to concentrate	10.8	11.2	8.0	13.8	14.8
15	Smells	11.0	10.8	10.0	15.6	12.2
16	Lack of exercise	12.6	15.0	15.4	11.2	10.4
17	Lack of organization	11.2	12.2	13.8	13.0	13.0
18	Poor leadership	9.8	11.8	13.4	13.6	14.0
19	Temperature and humidity	10.8	14.0	14.4	15.4	15.6
20	Lights while sleeping	15.6	11.5	16.0	14.8	17.2
21	Lights while awake	18.6	17.8	17.6	17.8	15.0

TABLE 46

Mean Ranks Assigned to the Items on the Modified NRL Scale to Indicate  
"How Often" They Bothered the Test Crew

Rank	Scale Item	DAY OF RUN				
		Pre	9	16	23	30
1	Food	5.8	1.2	7.4	4.0	7.0
2	Noise	3.8	3.2	6.8	6.2	6.8
3	Toilet facilities	6.2	6.0	7.6	5.2	6.6
4	Behavior of others	9.8	9.5	6.6	8.0	5.8
5	Crowding of the chamber	9.0	12.0	7.0	7.6	9.2
6	Boredom	8.8	12.0	10.6	9.2	6.2
7	Lack of privacy	7.2	9.5	8.2	12.0	8.6
8	Dirt	11.6	12.5	13.0	7.2	8.0
9	Lack of water for washing	9.0	7.5	12.4	9.4	12.8
10	Worries about the outside	14.4	12.8	9.2	11.4	9.0
11	Trouble sleeping	14.8	9.8	13.8	9.6	9.4
12	Smells	14.0	7.8	9.0	15.2	11.4
13	Lack of exercise	8.6	7.5	11.6	13.6	12.2
14	Bunks	15.2	11.0	11.4	11.4	13.8
15	Not able to concentrate	12.8	13.8	9.2	12.4	13.0
16	Physical symptoms	17.2	14.2	12.6	9.6	13.6
17	Lack of organization	11.6	12.5	15.0	14.6	13.0
18	Poor leadership	13.6	14.5	13.2	14.0	14.6
19	Lights while sleeping	13.8	14.5	15.0	16.2	15.0
20	Temperature and humidity	9.8	18.0	14.0	16.6	15.8
21	Lights while awake	16.0	18.5	17.4	16.2	13.4

TABLE 47

ANALYSIS OF VARIANCE OF THE MYERS SCALE "POSITIVE" MOOD  
 FACTOR FOR THE "NOW" ADMINISTRATION AS A FUNCTION  
 OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	4	516.3	4.05	< .025
SUBJECTS	4	464.3	3.64	< .05
DAYS x SUBJECTS	16	127.4		
TOTAL	24			

TABLE 48

ANALYSIS OF VARIANCE OF THE MYERS SCALE "NEGATIVE" MOOD  
 FACTOR FOR THE "NOW" ADMINISTRATION AS A FUNCTION  
 OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	4	24.8	1.16	> .20
SUBJECTS	4	42.8	2.00	< .20
DAYS x SUBJECTS	16	21.4		
TOTAL	24			

TABLE 49

ANALYSIS OF VARIANCE OF THE MYERS SCALE "POSITIVE" MOOD  
 FACTOR FOR THE "THEN" ADMINISTRATION AS A FUNCTION  
 OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	3	234.3	3.12	< .10
SUBJECTS	4	667.0	8.89	< .01
DAYS x SUBJECTS	12	75.0		
TOTAL	19			

TABLE 50

ANALYSIS OF VARIANCE OF THE MYERS SCALE "NEGATIVE" MOOD  
 FACTOR FOR THE "THEN" ADMINISTRATION AS A FUNCTION  
 OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	3	8.0	0.62	> .20
SUBJECTS	4	89.0	6.85	< .01
DAYS x SUBJECTS	12	13.0		
TOTAL	19			

TABLE 51

ANALYSIS OF VARIANCE OF THE MYERS SCALE "POSITIVE" MOOD  
FACTOR FOR THE "NORMALLY" ADMINISTRATION AS A  
FUNCTION OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	4	111.0	3.78	< .025
SUBJECTS	4	551.8	18.77	< .01
DAYS x SUBJECTS	16	29.4		
TOTAL	24			

TABLE 52

ANALYSIS OF VARIANCE OF THE MYERS SCALE "NEGATIVE" MOOD  
FACTOR FOR THE "NORMALLY" ADMINISTRATION AS A  
FUNCTION OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	4	15.20	3.34	< .05
SUBJECTS	4	67.10	14.75	< .01
DAYS x SUBJECTS	16	4.55		
TOTAL	24			

TABLE 53

ANALYSIS OF VARIANCE OF THE SUBJECTIVE STRESS SCALE  
RESPONSES AS A FUNCTION OF TIME IN THE CHAMBER

SOURCE	df	MS	F	P
DAYS	6	569.3	1.59	< .20
SUBJECTS	4	48.5	0.14	> .20
DAYS x SUBJECTS	24	359.0		
TOTAL	34			

TABLE 54

ANALYSIS OF VARIANCE OF THE HOSTILITY SCALE RESPONSES  
REFLECTING FEELINGS TOWARD THE GROUP AT THE LEAST  
FAVORABLE TIME AS A FUNCTION OF TIME IN THE  
CHAMBER

SOURCE	df	MS	F	P
DAYS	3	509.7	63.71	< .01
SUBJECTS	4	537.8	73.48	< .01
DAYS x SUBJECTS	12	8.0		
TOTAL	19			

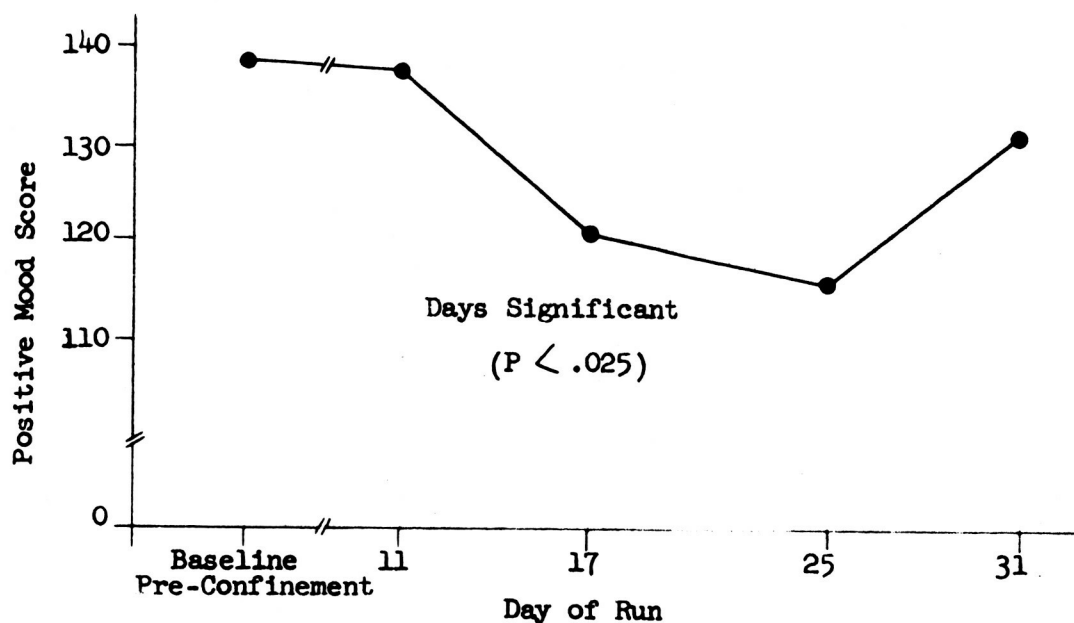


Fig. 54 EXTENT OF CHECKING OF POSITIVE MOOD WORDS TO INDICATE HOW MUCH THEY APPLIED "NOW" AS A FUNCTION OF TIME IN THE CHAMBER

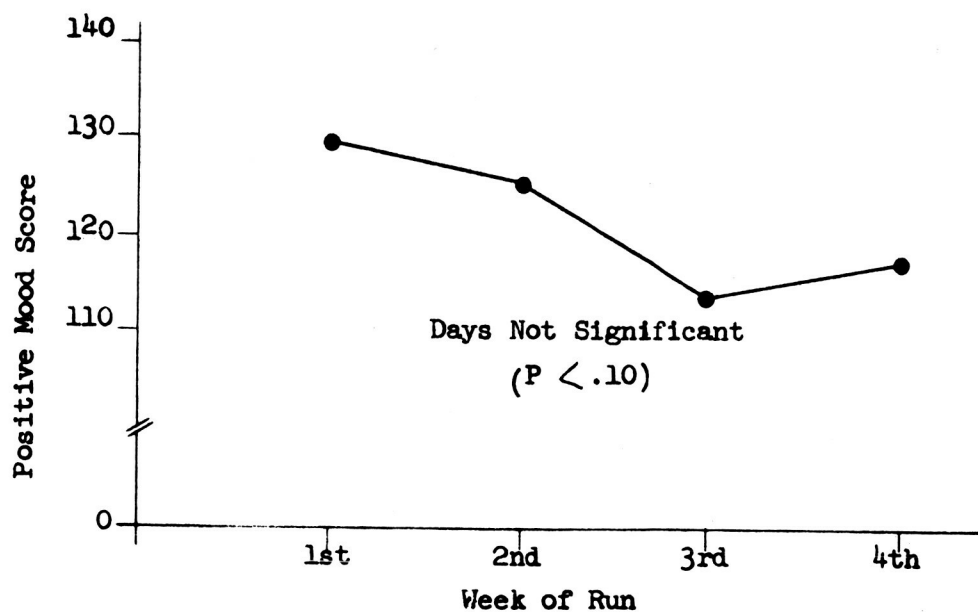


Fig. 55 EXTENT TO CHECKING OF POSITIVE MOOD WORDS TO INDICATE HOW MUCH THEY APPLIED "DURING THE LAST WEEK" (THEN) AS A FUNCTION OF TIME IN THE CHAMBER



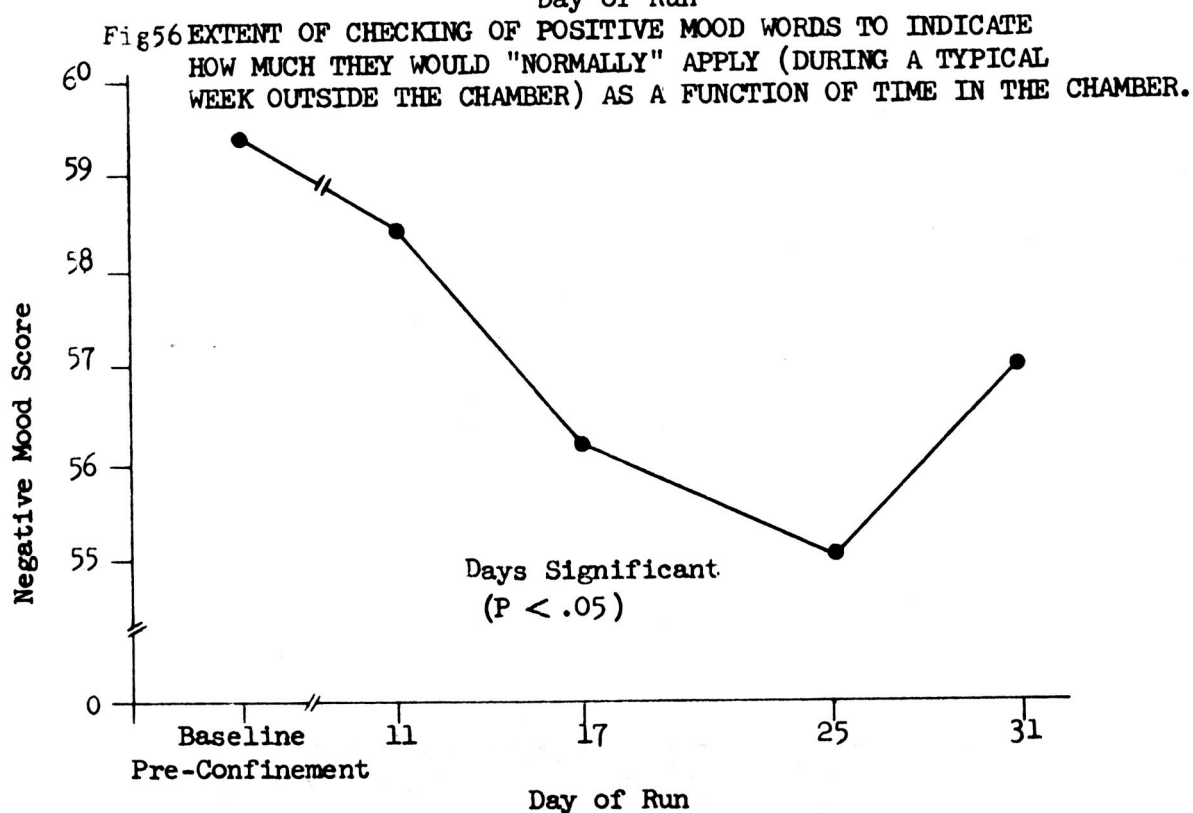
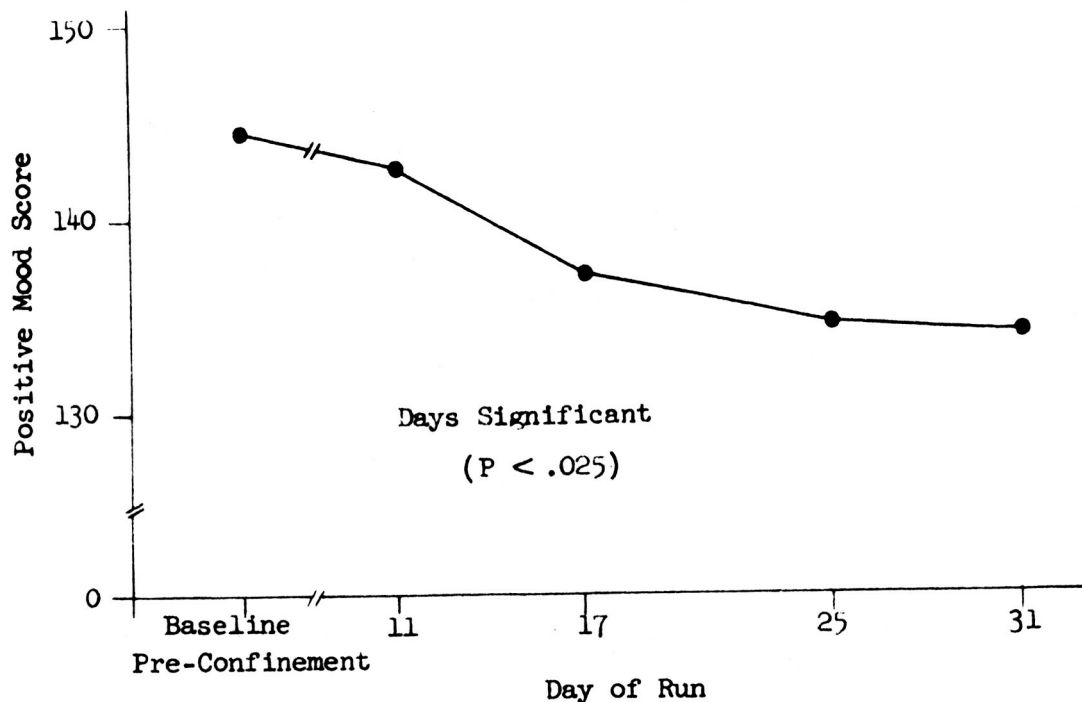


Fig. 57 EXTENT OF CHECKING OF NEGATIVE MOOD WORDS TO INDICATE HOW MUCH THEY WOULD "NORMALLY" APPLY (DURING A TYPICAL WEEK OUTSIDE THE CHAMBER) AS A FUNCTION OF TIME IN THE CHAMBER

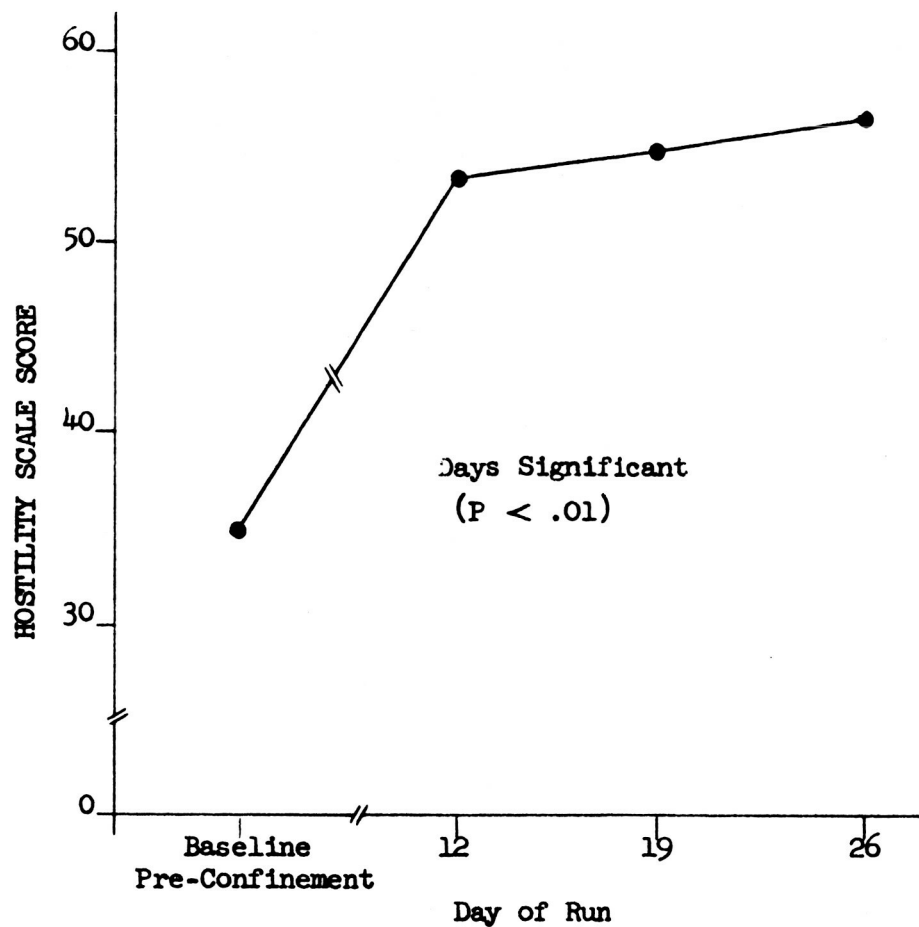


Fig. 58 HOSTILITY SCALE SCORES BASED UPON HOW  $S_8$  FELT TOWARDS THE "GROUP" AT THE LEAST FAVORABLE TIME AS A FUNCTION OF TIME IN THE CHAMBER

DISCUSSION AND RECOMMENDATIONS

Although some valuable information was obtained during the thirty day MESA confinement, extremely poor motivation of the test crew to participate in the psychological assessment program resulted in questionable data on several of the measures. In spite of this serious limitation several aspects of the crew's behavior and experiences bear discussion to the extent that they shed light upon future tests similar to MESA, and upon human factors aspects of future long-term space missions.

#### I. Crew Motivation

The attitudes, feelings and "sets" adopted by persons participating in psychological studies are of critical importance in determining experimental results. Considerable care must be employed to establish sets and motivations which are appropriate to the situation. In the MESA program, which was always referred to primarily as a hardware systems check-out, the manipulation of the motivations of the test crew to cooperate fully in behavioral testing was not satisfactory. Several reasons appear to have contributed to this.

The original psychological test program represented a large work load. It was partly designed to fill large amounts of expected "free" time. As the MESA program developed, however, life support systems monitoring and maintenance activities were extensive enough to fill much of this time. The workload imposed by the behavioral tests thus was out of line with other requirements, and with the attitudes of both test personnel and test subjects. Because the behavioral test program was viewed by the subjects as being of secondary importance, and since reductions in the number of tests and in the psychological monitoring schedule were not permitted prior to the beginning of the confinement period, the annoyance toward the program was partly justified.

Another important consideration was that some of the subjects possessed negative attitudes toward the psychological test program prior to the beginning of confinement. These attitudes spread rapidly to other crew members early in the run and ultimately led to overt criticism of the psychological tests. The pronouncements about the tests by certain crew members, who claimed expertise in psychological testing, also took their toll on other crew members as well as outside test personnel. The result was a crew motivation state which produced at least some unreliable and invalid psychological test data.

To the extent that such negative attitudes may also, in fact, have led to a reduction in the usefulness of some data from other parts of the MESA program, crew matters clearly need to be better handled in future tests. The test crew must clearly understand the importance of each aspect of the program and must be sympathetic with the requirement to endure the various hardships. If crew members were selected because of their high motivations to make all aspects of such a future program a success, one could expect a quite different picture than that obtained here. For instance, the criticisms registered against the food, toilet facilities, noise, medical and psychological evaluations, the required hospital stay, behavior of outside personnel, and poor design of various pieces of equipment, might all have been minimized by having an appropriately motivated crew.

In addition to obtaining a highly and appropriately motivated crew for future tests similar to MESA, greater efforts need to be expended in crew indoctrination and training. A considerably longer period of time for crew members to become conversant with and involved in the many facets of the test program and a greater attempt to impart an understanding of the background and goals of such a program would appear to be a minimum requirement.

## II. MESA II Behavioral Effects

Overall the crew handled the confinement well. No serious effects on performance were observed throughout the thirty day confinement period. This finding is consistent with much of the current literature on individual and group confinement showing that man is capable of adapting reasonably well to a wide variety of confined and/or isolated environments (see The Boeing Company, for a summary of confinement studies).

In considering the results of the MESA behavioral assessment program a number of reservations must be kept in mind. There was no control group whose performance could be compared with that of the crew. Testing prior to confinement provided familiarity with most of the tests, but, because of time limitations, was not sufficient to establish a practiced baseline on any of the performance tasks. Motivation to work on the tasks was generally low and certainly had a considerable effect towards reducing performance, especially on those tasks which were relatively difficult and uninteresting to the subjects.

In the area of sensory functioning several significant changes occurred. The changes in phoria were considered relatively valid, since this task was not so obviously related to motivation as most. An average increase in a near point exophoria (lateral divergence of the eyes from the proper relationship for vision at near point) of six diopters was observed in the last two thirds of the confinement, with essentially total recovery to the pretest level at the time of post testing. This change is similar to that observed in students during reading stress, who show exophoria during the stress and esophoria afterwards (personal communication from Dr. Gerald Getman, LaVerne, Wisconsin). An exophoria of this magnitude would probably be associated with increased eyestrain in any prolonged visual task, perhaps with a tendency for momentary blurring. However, it does not necessarily imply any decrement in visual acuity or depth perception.

CFF (critical flicker frequency) showed a significant improvement throughout the period of confinement, with a drop afterwards. As mentioned earlier, many uncontrolled variables could have contributed to these changes. However, to the extent that they may be valid, it is interesting to compare these results with the decrement in CFF generally found in persons known to have received toxic materials. The hyperclean environment in the chamber during MESA II may have had the opposite effect. Unfortunately, no comparative CFF data could be collected during MESA I when toxicity apparently was a problem.

The two vision tests which were most difficult for the subjects, acuity of resolution and stereopsis (depth perception), demonstrated this by a considerable lack of data. The three subjects who did provide some measure for stereopsis showed large trends but they were highly individual and not related in any simple fashion to the visual aspects of the confinement.

As noted in the Results section, the acuity test provided even fewer data. Their interpretation was made more difficult by the easier testing technique introduced after Day 7 as part of the reduction in the testing program. The general tendency for improvement over time with a relatively large improvement at the post test suggests continued learning on the task, combined with some depression of performance while confined. In view of the experimental work by F. A. Young ( American Journal of Opthamology, 52, 1961, 799-805; also work in progress) which suggests that in primates visual acuity at far point is reduced, perhaps irreversibly, by continued restriction of vision to short distances, this lack of an adequate experimental test of visual acuity is particularly unfortunate.

Subject D, on his one relatively valid acuity score during confinement, provided a much worse score than before or after the run. He also reported suffering considerable eyestrain immediately preceding and throughout confinement. He interpreted this in terms of the emotional tension associated with his responsibilities on the MESA program.

There was some evidence for a decrement in complex auditory discrimination, as measured by intelligibility testing, late in the run. This could have been the result of the continued exposure to high noise levels. However, since Test 2 showed a decrement only if skipped passages were scored as incorrect, it appears at least as likely that the decrement is related to the subjects' lack of willingness to exert themselves in taking the test.

In view of the difficulties encountered in administering the pitch discrimination test, no general statements on the perception of pitch appear warranted.

In the area of psychomotor performance, as measured by tracking and monitoring, there was a general trend (sometimes significant and sometimes not) for improvement over time. An exception was meter monitoring, which showed some reversals in performance, but chiefly for only two subjects. Lacking an appropriate control group with which to compare learning rates, it is impossible to state whether the confinement situation had any detrimental affect on performance. However, the effect, if it did occur, was not sufficient to cause a reversal in the slope of the learning curve.

Time estimation ability did not change significantly throughout confinement. This does not mean that the subjective sensation of the rate of time passage was unchanged. To follow their schedule the subjects were required to remain quite conscious of time and any changes in time sensation might well have been corrected for. Although no time estimation changes occurred there was evidence from questionnaire data that subjects felt time was dragging considerably by the end of confinement.

In the areas of subjective experience and group dynamics there were several interesting findings. In addition to the motivation problem noted previously, the most serious difficulties encountered during confinement appeared to have been interpersonal. The major portion of interpersonal conflicts appeared to be centered within the test crew although sometimes outside personnel were involved. The significant increases (noted on psychological tests) of irritability and hostility directed toward crew members or toward the crew in general were readily substantiated by observations and by post test interviews with the subjects.

It is clear that differences among personalities, personal habits, and the differences in motivation for being in the test situation, all led to conflicts among crew members which were energy consuming and annoying at best. Those persons most bothered by such conflicts later expressed concern about how well they might have been able to handle these problems had the test been scheduled for a longer period of time.

In general the confinement experience did not appear to be particularly productive of psychological stress as evidenced by no changes in the checking of the Subjective Stress Scale throughout the thirty days. In addition there were no unusual visual or auditory experiences such as hallucinations during confinement. Aside from the high levels of irritability and hostility exhibited by most of the subjects, none of the behavior observed during the run would be viewed as abnormal.

In terms of those things most often listed throughout the run as being annoying or bothersome to the subjects (Modified NRL Scale), the behavior of others, noise, food and toilet facilities were among the top three of twenty-one categories most often. Also appearing among the top three were: crowding of the chamber, followed by boredom, trouble sleeping, and worries about the outside. In a previous study, the sorts of things which bothered persons confined in a large fallout shelter (see NRL Report 5882) were quite similar. Among the top five in that study were: crowding of the chamber, behavior of others and food. Although the situations were quite different the reactions to both environments were similar and indicate that many of the problems in such circumstances are interpersonal.

One of the more interesting findings of the behavioral program was that of changes in mood. As the confinement progressed, subjects checked fewer and fewer positive words on the mood adjective check list (Myers Scale). This significant drop appears to represent a gross lowering of feelings of well being, comfort, pleasantness, and the like. Interestingly, negatively intoned words were not checked with increasing frequency, even though there was much expressed negativism during the run. The mood changes observed throughout the confinement period were accompanied by shifts in the ratings subjects gave to the checklist to indicate how the words would "Normally" apply to them. In general, throughout confinement these positive and negative baseline scores became progressively lower as compared with the "Normally" baseline data gathered before confinement. These findings suggest that a restructuring of mood patterns may take place during confinement which could well be important on long-term missions. Although the small number of subjects used here makes these data speculative at best, mood during confinement looks like a productive area for future careful study.

The inventory used to sample changes in experiences as a function of being in the chamber showed significant changes as follows: a decrease in feelings of well being and general positive feelings, an increase in the tedium of time, a large increase in annoyance directed toward the MESA crew members, and considerable hostility toward the psychological test program per se. The findings from the inventory tie nicely with the mood checklist in showing a general drop in positive feelings. In similar fashion the highly significant increase in group annoyance revealed by materials from the questionnaire was consistent with all of the other evidence relating to interpersonal problems. There did seem to be some evidence from the inventory that intellectual inefficiencies were occurring. Interviews later substantiated that several of the subjects felt they could do little or no heavy reading due to lack of ability to concentrate. One man was a clear exception to this, however.

In summarizing the behavioral results it should be clear that, aside from the potentially explosive area of interpersonal conflicts, few changes in performance appear to be caused by a test situation such as that of MESA. Those changes which were observed during this study were relatively small and were generally not suggestive of serious problems.

### III. Human Factors Recommendations

There seems to be ample evidence from the current study that human factors considerations are even more important during prolonged confinement than would usually be the case. Although the crew chosen for MESA II was not as motivated as would be desired for actual missions, their greater tendency to be critical may have helped to pinpoint those things which might unnecessarily become problems on extremely long missions.

Many equipment matters were sources of irritation for the MESA crew and in some cases increased interpersonal frictions as well. Some examples may be useful. One crew member expressed hostility towards the pumps used to deliver water for drinking and food preparation because of the large amount of force required to operate them. More important, the man who followed him in their use became irritated at him because he often left the handles pulled out, rather than resetting them after obtaining his water. A similar conflict involved the relatively complex toilet facility. One subject frequently failed to complete all of the steps in its cycle, leaving some of his work for the next user. This led to another unnecessary source of friction. One solution to such problems may be to design the equipment so the operator is unlikely to leave it at any point except the beginning of its next cycle. Other



examples of problems in the MESA setting were various pieces of equipment for which cleaning and routine maintenance activities were unnecessarily difficult, and psychological measurement equipment which was uncomfortable and/or difficult to use.

The work-rest cycle employed in MESA II appeared to be fully satisfactory. In general, subjects adapted readily to the new sleep pattern required by the eight-four cycle. The amount of sleep was felt to be adequate after the first few days. The splitting of the day into two parts broke up the relatively monotonous duty hours and was felt by the crew to have aided considerably in defeating boredom. Along these same lines, they felt that breaking the 30 day duration of the confinement into several smaller units, perhaps by celebrating the weekends in some simple manner, would have made its length more acceptable. A limited example of such a break was the Sunday paper, which the crew received and considered very important.

Most of the crew indicated a need for some privacy. The fact that the work-rest cycle provided a certain amount of privacy by placing people in different places appeared to be one of its most appreciated features. The visual and auditory isolation of the sleeping quarters both enhanced the feeling of privacy in them and facilitated sleeping. The isolation of the sleeping quarters appears to be important in any system where sleep and activity are to occur concurrently.

The layout of facilities (e.g., the placement of objects, the size of aisles, etc.) to make it possible to avoid as much bumping into one another as possible appears to be desirable. An important source of friction among crew members seemed to stem from having to squeeze by other people (who were often perceived as too rude to move) in the restricted passageways.

The MESA crew felt that they adapted reasonably well to the high noise which characterized their environment, but most felt that noise had contributed to their level of irritability. Although no criteria can be advanced about how much noise would be allowable, it is clear that any possible noise reduction in future systems would be beneficial.

No measurements of olfactory sensitivity were taken. However, there was evidence to indicate that subjects increased in their ability to perceive specific odors while living in the very clean atmosphere. In post test interviews subjects mentioned that many odors they would never notice normally became quite easy to detect. They also mentioned that bodily odors (flatulence, bad breath and perspiration) became quite offensive. This problem would appear to have implications

both for bathing facilities and for the diet. It also has favorable implications for the crew's safety, since their increased ability to perceive odors, if reliable, should assist in providing a warning of many types of system malfunctions. One other aspect of the olfactory problem was the crew's comments about the lack of food odors while eating. With many of the normal pleasures of life denied, enhancing the olfactory appeal of the diet would be a much appreciated luxury in similar missions.

#### IV. Recommendations for Future Tests

The selection of highly motivated subjects would probably be the single most important improvement that would aid psychological assessment in future tests similar to MESA. It would also considerably improve the chances for much other information, such as crew opinions about food, to be valid as well.

From a test administration standpoint several factors appear to be important. First, in order to obtain the cooperation necessary to carry out psychological experimentation, the experimenters need to exercise much more control over crew motivations and attitudes than was possible here. At a minimum the subjects must understand the reasons for and be willing to undergo the hardships imposed by the behavioral program. A more disciplined overall test situation including considerably more support of the psychological measurement program by test personnel and contract monitors would be helpful, as well as representing better simulation of what an actual mission would be like.

Many of the psychological tests which could provide valuable information about the effects of such unusual environments on behavior need careful development and checkout.

This is a costly process both in time and money. The criticisms registered against the MESA psychological tests, while in many cases unfounded, are an indication that some were unnecessarily difficult or uncomfortable to take. It is also true that due to time and money limitations many were not properly pilot tested and improved. In future programs, either expectations must be trimmed or funding for behavioral assessment increased.

Finally, the training of test personnel and crew members must be long enough to be sure that the necessary knowledge about all aspects of the project is imparted and that all personnel have an opportunity to build up confidence in and respect for one another. In the behavioral area this would involve assigning much more training time to clarify the objectives of the test program, to mold attitudes, and to establish stable baselines on the selected performance tasks.

Unless most of these recommendations were included in future projects involving behavioral testing, it would be the opinion of the psychologists who were involved in the MESA program that such testing would be of limited value.

## SUMMARY

Various psychological tests were used to evaluate the behavior of a five man crew confined for 30 days in a test of the MESA life support system. Tests were included to assess visual and auditory functioning, perceptual and motor skills, group dynamics and individual attitudes and experiences.

No control groups were available for behavioral comparisons. Moreover, due to time limitations, pretesting for most of the tasks provided familiarity but not stable baseline measures of performance. The generally negative attitudes of the subjects towards the behavioral assessment program necessitated a considerable reduction in its scope before the end of the first week of confinement. Their poor motivation made much of the psychological data highly questionable.

In general there were no serious performance decrements on the tests actually taken by the subjects. However, there are several findings worthy of mention.

There were several changes in sensory functioning. An exophoria at near point of six diopters occurred with total recovery by the time of post test. This condition would probably be associated with increased eyestrain in any prolonged visual task. Critical flicker frequency (CFF) improved throughout the run, with a drop at the post test. These changes may reflect the hyperclean environment in the chamber. A decrement in a complex auditory discrimination test (intelligibility) occurred but may have been related to motivational factors. There was some suggestion of a slight decrement in visual acuity and no changes in depth perception or pitch discrimination.

Perceptual-motor skills, as measured by tracking and monitoring tasks, showed general improvement throughout and after the run. With no control group it is not possible to determine whether this enhancement is due to anything other than learning.

There was no measured increase in psychological stress associated with the run and no unusual visual or auditory experiences. Irritability and hostility levels were high but not abnormal for group confinement. The most serious problems were interpersonal conflicts, mostly among crew members but also affecting outside personnel. Poor crew motivation undoubtedly contributed to these problems.

Those things most often listed during confinement as being bothersome or annoying were behavior of others, noise, food and toilet facilities. Also, occasionally appearing among

the top three were crowding of the chamber, boredom, trouble sleeping and worries about the outside. Decreases were indicated during the run in feelings of well being and in general positive feelings. Increases were noted in the tedium of time, annoyance directed at the MESA crew members and hostility towards the psychological test program. Positive mood dropped while negative mood did not change.

It was concluded that the MESA thirty day confinement was not particularly difficult or stressful for the crew. Those behavioral problems which did exist appeared to stem mostly from poor motivation and centered primarily around the area of interpersonal friction. It is clear that human factors considerations (difficulty of use and maintenance of equipment, crowding of the chamber, and the like) led to irritations and that these often led to interpersonal friction as well. Standard human engineering considerations appear even more important for systems involving crowded, confined environments.

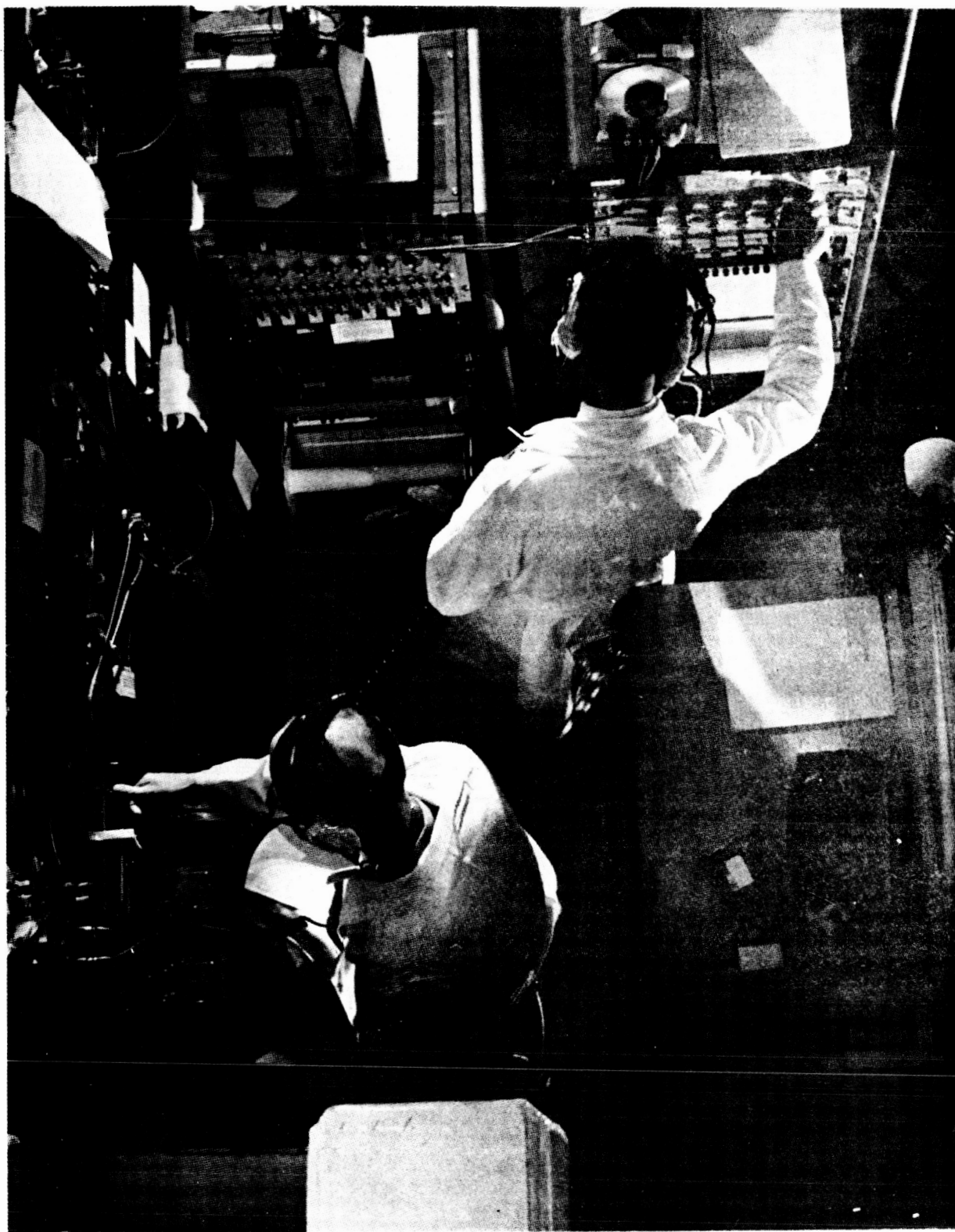


Photo 28: PROGRAMMING AND RECORDING EQUIPMENT AT PSYCHOLOGICAL MONITORS STATION

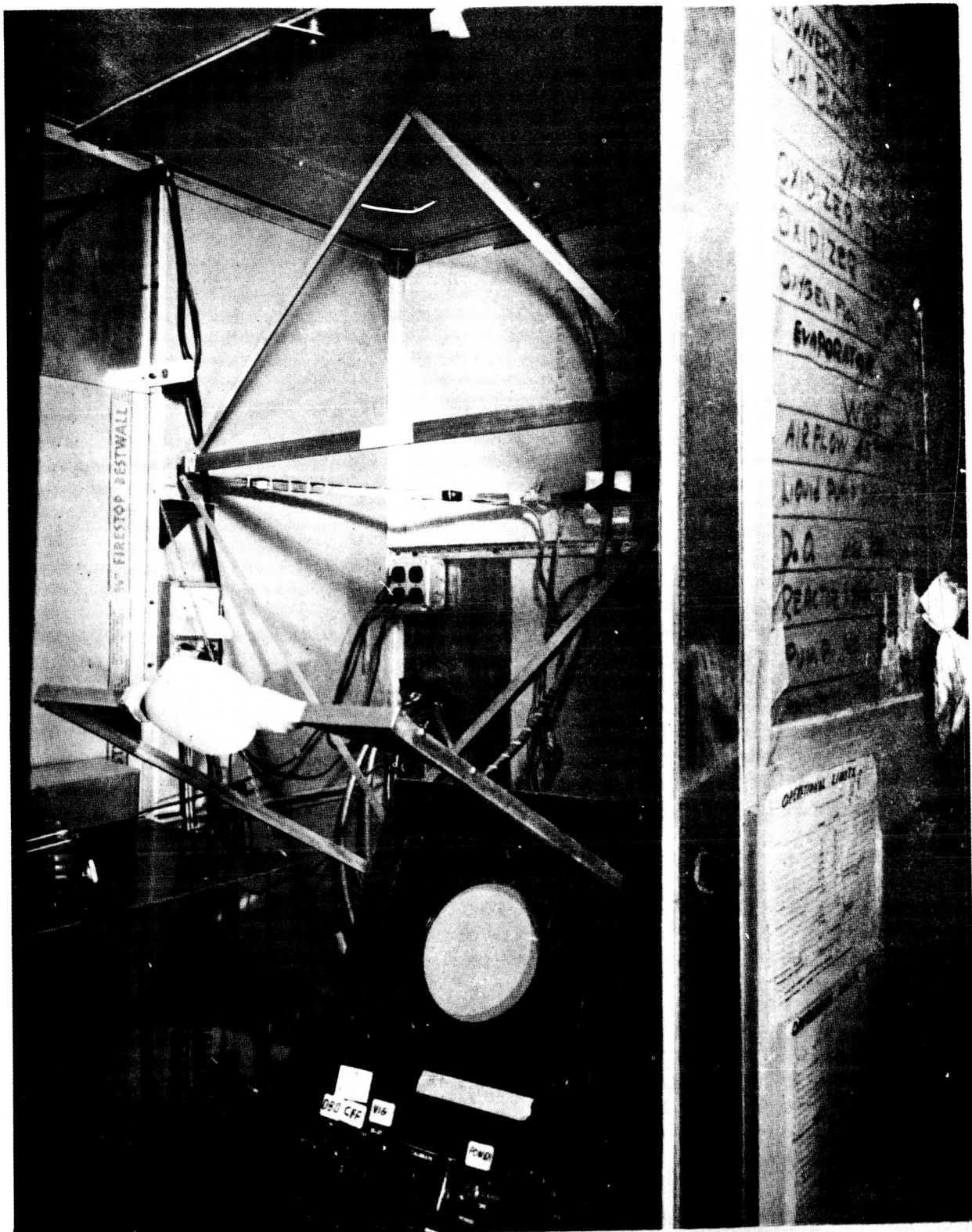


Photo 29: AUDIO VISUAL BOOTH WITH DISPLAY USED FOR MEASURING CFF



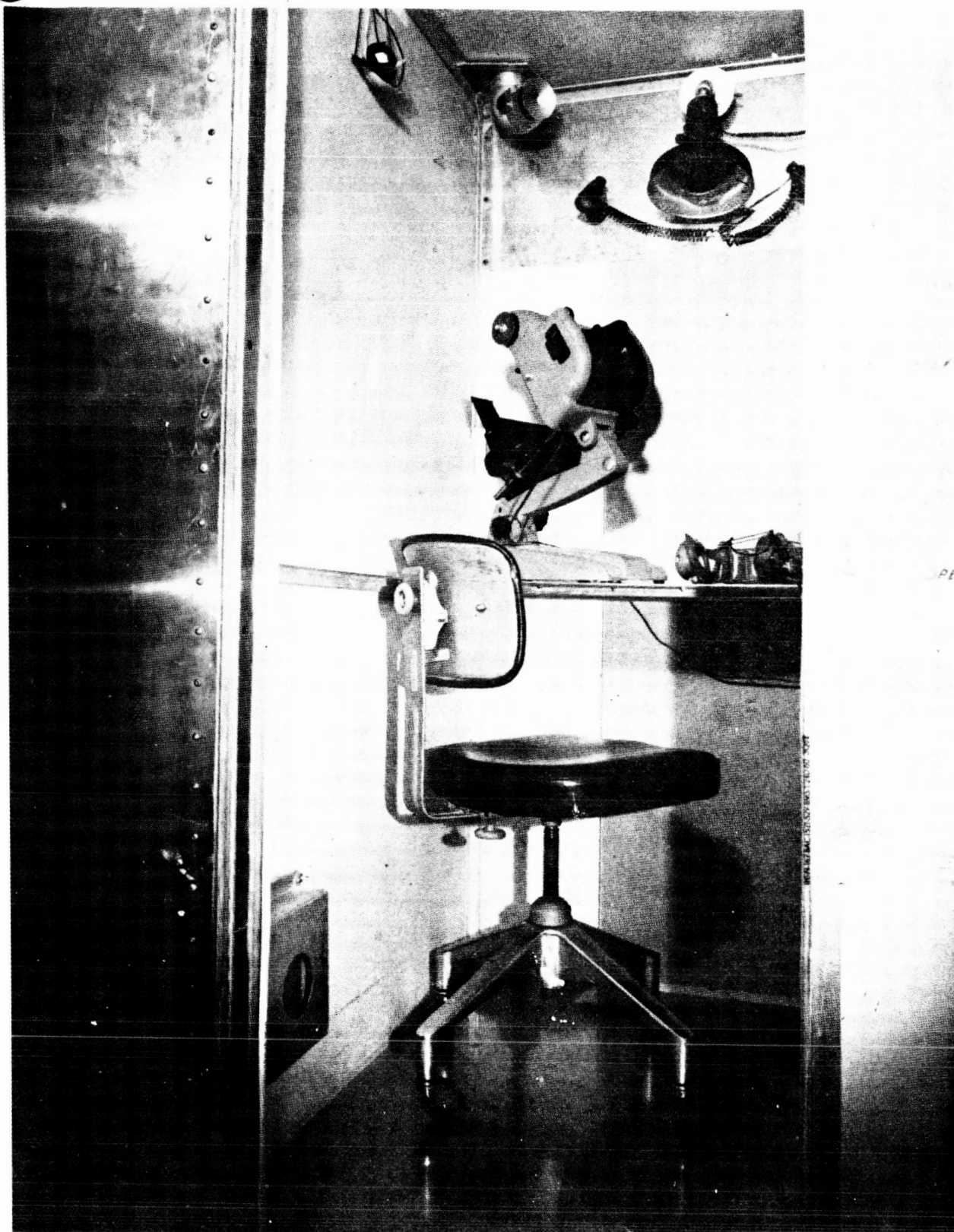


Photo 30: KEYSTONE STEREOVIEWER IN AUDIO VISUAL BOOTH



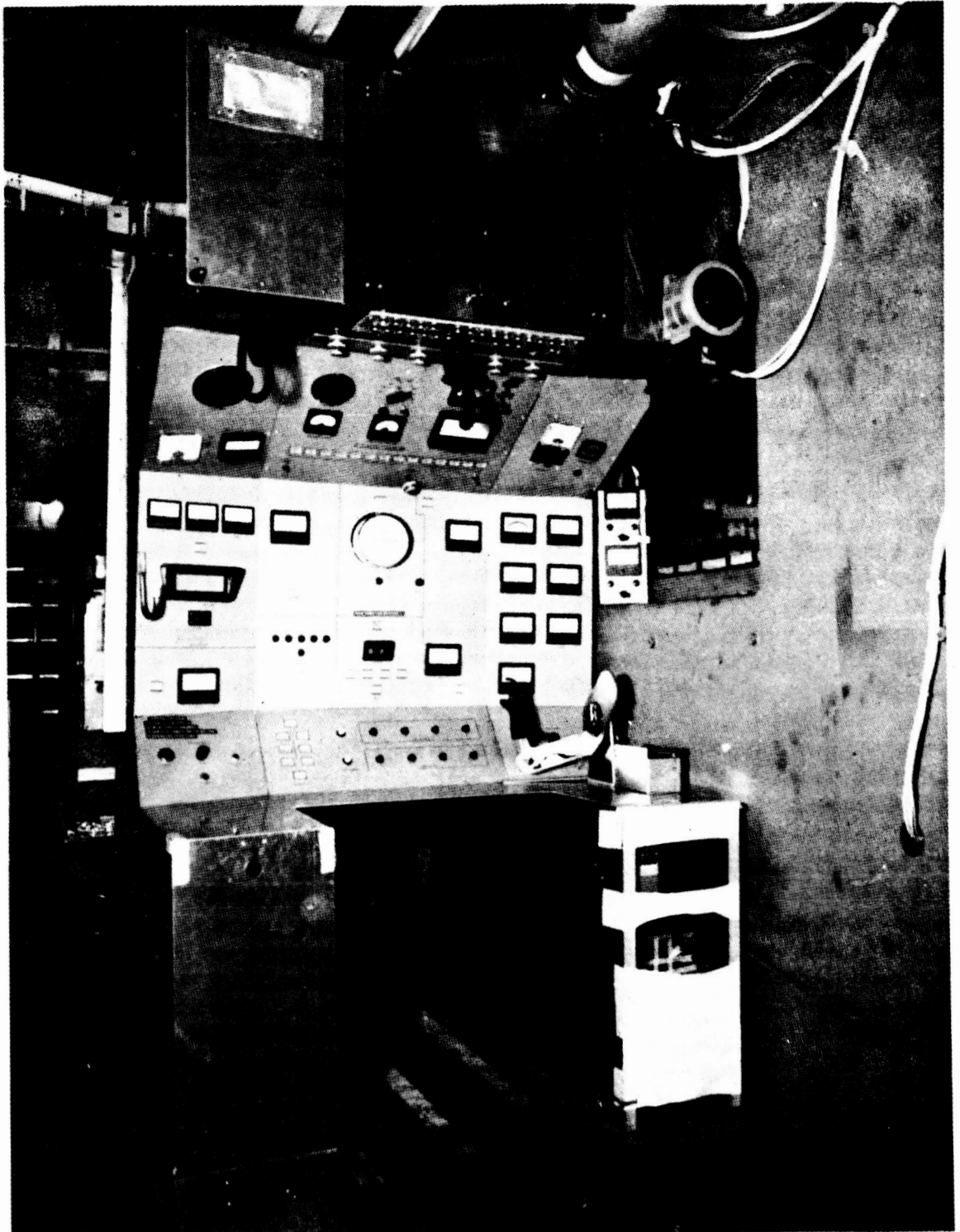


Photo 31: TRACKING AND MONITORING TASKS AT OPERATORS STATION  
ON COMMAND CONSOLE

PHYSIOLOGICAL

This section covers the medical clinical laboratory, urinary metabolites and bacteriological monitoring of the crewmen for both MESA I and MESA II.

6.5.1 MESA I6.5.1.1 Medical and ClinicalA. Subjects

The five subjects participating in Project MESA comprised three Boeing employees: C. M. Proctor, age 45; R. J. Farrell, age 25; R. H. Lowry, M.D., age 42 and one military, Maj. E. F. Westlake, USAF, age 45; one NASA representative, R. J. Barnicki, age 27. All subjects were given a comprehensive flight-type physical examination approximately two weeks prior to the test with follow-up studies in accordance with a planned clinical examination schedule.

B. Course in Chamber

The subjects entered the closed environmental simulator at 8:00 am on Tuesday, July 16, 1963. Difficulties in operating the various subsystems developed shortly thereafter and progressed until the run was aborted at 2:00 pm on Saturday, July 20. Within 48 hours after the start of the run an odor problem became obviously apparent and all subjects developed varying degrees of nausea, anorexia and malaise progressing to overt retching and vomiting in a few instances. No headache, respiratory complaints or abdominal pain was reported and there was no fever leucocytosis or change in erythrocyte sedimentation rate determined.

Post Test

Initial examination on the day of abort did not reveal any abnormal findings and follow-up physical examinations by internists on Monday, July 22 were also not significant although anorexia and nausea persisted. During the next 72 hours, 4 of the subjects (Proctor excluded) developed herpetiform lesions of the mouth and/or lips with sore gums unassociated with known fever or regional lymphadenopathy. Unfortunately, these lesions were not observed by anyone on the medical staff and scrapings were not obtained. They persisted for approximately one week clearing as the subjects gradually regained appetite, freedom from nausea and a feeling of well-being.

### C. Laboratory Data

All clinical laboratory tests during the course of the run were within normal limits and are tabulated in the attachment together with a battery of paired sera determinations for creatinine, bilirubin, thymol turbidity, and transaminase. No hepatotoxic effect is indicated.

In an attempt to establish the etiology of the post-run aphthous stomatitis, paired sera were also submitted to the Department of Virus Diseases, Division of Communicable Disease and Immunology of the Walter Reed Army Institute of Research for possible diagnostic changes in viral complement fixing or neutralizing antibody titers. No significant changes in titer were determined for Herpes Simplex, Coxsackie A-9, or ECHO types 6, 9, and 16 all of which have previously been implicated in outbreaks of acute gingivostomatitis.

### D. Summary

All test subjects were intensely motivated and accepted considerable personal discomfort during the course of the test. The combination of an intense nauseating odor, unpalatable food and continual mechanical breakdown, however, ultimately destroyed morale and undoubtedly was a primary cause of their symptomatology. The aphthous stomatitis may have been a reaction to emotional stress, of undetermined viral etiology, non-specific in origin, or related to an unidentified environmental contaminant.

#### 6.5.1.2 Urinary Metabolites

Catecholamines, calcium and hydroxycorticosteroid samples were taken for the aborted MESA I manned test. Due to the small number of samples taken, no usable data were obtained.

#### 6.5.1.3 Bacteriology - MESA I

##### PRE-TEST

The bacteriological studies which were carried out prior to the manned test consisted of the isolation and characterization of the bacterial flora of each subject in order to provide a baseline for studies to be carried out during the manned test. For each subject, cultures were made from samples taken from the nose, throat, skin, and feces. Standard techniques of isolation and identification were followed. The nasal flora of all subjects appeared to be of normal distribution except for the fact that one subject

was found to carry a coagulase positive Staphylococcus aureus. There was, however, no indication of a clinical infection. Throat flora of all subjects was considered normal except for the one instance in which the S. aureus was isolated. The pretest fecal flora of all subjects was found to contain predominately Clostridia and Bacteroides in the anaerobic population and E. coli and paracolon types in the aerobic group.

### 30-DAY ATTEMPT

Nasal samples taken on the fourth day of the test showed that, in addition to the one subject who yielded S. aureus prior to the test, two of the other subjects now carried a coagulase positive S. Aureus. Serological typing of these organisms showed that they were of the same type in the latter case. The phage type was different from the organism found prior to the manned test. Throat swabs taken on the fourth day from each subject showed the same picture with respect to S. aureus, except that the organism was only isolated from one of the two new "carriers". Examination of skin samples after four days of confinement were unremarkable except that it was possible to demonstrate the S. aureus on the skin of the pre-test "carrier". Fecal samples obtained during the time of confinement showed no remarkable changes when compared to the pre-test samples.

In summary, the manned chamber test did not last long enough for any valid conclusions concerning the effect of confinement on the bacterial flora of the subjects to be made.

## 6.5.2 MESA II

There were two manned tests in this program. The 17 day integration pre-test of February 1964 which included the last 4 days manned. This test provided the confidence necessary to conduct the 30-day manned test.

### 6.5.2.1 Medical and Clinical

#### A. 4 Day Pre-test

The five subjects participating in the 4 day shake-down run were Boeing employees: K. S. Brossel, age 43; F. T. Santler, age 28; J. R. Welker, age 36; P. W. Trush, age 26; and N. E. Johnson, age 21. Each subject received a comprehensive flight-type physical examination within the two week period preceding the test, was interviewed at least once daily during the course of the test, and was medically debriefed both on test completion and 48 hours post-test.

During the approximate 4 days spent in the chamber all subjects did remarkably well and were virtually free of symptomatic complaints. In no case was there any suggestion of nausea, food

intolerance or reduction in appetite. Although transient localized odors were noted there were no reports of headache, irritation of the eyes or respiratory tract or symptoms referable to CNS disturbance. All subjects commented on the desirability of reducing the over-all noise level and providing better temperature control particularly in the sleeping area. Three of the subjects felt they had passed more than their normal amount of flatus and attributed this to relative inactivity or dietary change. There were no other changes in bowel habits and no reported change in urinary habits.

One subject noted a "let down" feeling the evening of test completion but was fine the following day. Welker noted intermittent mild headaches during the 48 hours following the test but attributed these to prolonged reading and a tendency to constipation related to inactivity. Santler developed a mild aphthous stomatitis following the test without symptoms of upper respiratory infection. Two aphthous ulcerations were noted on examination and buccal scrapings and serum were obtained on 2/18/64 to be forwarded to the Walter Reed Army Institute of Research for possible bacterial/viral isolation and change in antibody titer. Results have not been reported to date. This type lesion is not unusual for this subject as he has had frequent similar episodes in the past.

Based upon the above medical information it was determined that the scheduled 30 day test could be conducted.

#### B. 30 Day Manned Test

Medical support for Project MESA II included medical monitoring and data collection in accordance with the clinical examination schedule as shown in Section 7.0. The test was regarded as embracing Human Experimentation and all subjects were required to sign a copy of a Consent Form.

##### 1. Subjects

The five subjects participating in Project MESA II comprised of W. A. Swenson ( ), age 26; P. W. Trush ( ) age 26; J. R. Welker ( ) age 36; Lt. Commander D. W. Robinson, M. D., USN (MC) ( ) age 33 who acted as crew medical officer; R. J. Barnicki, age 28 ( ). All subjects participated in test planning and the gathering of baseline data except subject (C), initially an alternate candidate, who was substituted on 3/2/64 (day 0) because of gross pyuria discovered in an original candidate.

Subject (D) had acted as crew member during Project MESA I and subjects (B) and (E) were crew members during the 4 day manned pre-test.

## 2. Pre-Test Procedures

Within the week preceding the test all subjects received a comprehensive flight-type physical examination including a Masters double 2-step electrocardiogram and baseline hematological, bacteriological, urinary and blood chemistry studies. All findings were within acceptable limits although extensive dental caries and chronic pyorrhea were again noted in subject (D). The space station diet was instituted on 2/23/64 (0-8) and the Gemini diet on 2/28/64 (0-3). During the transition period subject (D) complained bitterly regarding both diets noting bloating, belching and flatulence following meals with mild nausea associated with specific items. He had similar complaints of variable degree throughout the entire course of the test. The degree to which all subjects adhered to dietary restriction during the transition period is open to question.

## 3. Test Procedures

### A. Medical Monitoring

Medical monitoring was accomplished by a physician familiar with personnel subsystems functions in conjunction with the crew medical officer. During the first 7 days health status of the crew and test progress were appraised at 6 hour intervals; thereafter, crew members completed a daily health questionnaire each morning (copy attached) and underwent a confidential tape recorded debriefing over a closed loop communication channel. Consultation with the crew medical officer was effected whenever circumstances justified. Daily electrocardiogram, blood pressure, pulse rate, temperature and body weight were obtained and the periodic blood studies and urinalyses performed are individually tabulated in the attached clinical laboratory reports. All values were within the range of normal variation or laboratory error with the exception of methemoglobin levels which are discussed below. Fluctuations in body weight and fluid balance are covered under nutritional considerations.

Clinically all subjects remained in good-excellent health throughout the entire test with few exceptions. One medically based Unplanned Event Form was submitted on 3/3/64 (0 +1) because of tension headache and vomiting (Subject C) which was of short duration and did not recur. Other wise, only the expected incidence of headache and dietary induced gastro-intestinal complaints were noted which responded well to carefully prescribed doses of ASA and Maalox. The nausea and obnoxious odor present during MESA I were completely absent.

Baseline and periodic methemoglobin (Met-Hgb) determinations were taken on all subjects as an index of the presence of environmental or dietary oxidants indeterminate by other methods. Values are tabulated in the individual clinical laboratory reports and Met-Hgb. in ms. % is plotted chronologically in the attachment. The data points group themselves into 3 time periods related to dietary intake. Up to and including day 0 (chamber entry), during which time the diet was not rigidly controlled, the range of values is large. Thereafter, a definite trend becomes apparent with all values (except Subject B) peaking to a level of over 0.6 gms. % on day 0 +4, the midpoint of Gemini diet, with subsequent decline to the end of the test. The validity and significance of this peak, although repeated, was questioned and dual samples from the subjects and 3 controls were submitted to the original laboratory (SRL) and an alternate laboratory (SL) for comparison purposes on 3/12/64 (0+10). The results of these comparative tests are tabulated in the attachment and are in reasonable agreement indicating that differences between subjects and controls are not greater than the apparent limit of test accuracy. This lends credence to the relative accuracy of the previously obtained peak values which, although well below symptomatic threshold, are elevated above the accepted normal (3% Met-Hgb). Admittedly inconclusive, this suggests the possibility that the Gemini diet may contain an oxidant-preservative (nitrite) which was responsible for the elevated levels obtained.

#### 4. Post-Test Procedures

Following successful completion of the test all subjects were placed under close observation at Providence Hospital for a period of 3 days during which time comprehensive physical examinations were performed by an internist and follow-up data obtained. No significant changes from the pre-established baseline were found. A final battery of laboratory data were obtained on 4/7/64 (0+36) and all subjects released from further medical observation.

#### 5. Summary

All subjects successfully completed the 30 day test without impairment of health. One incident of tension headache and vomiting occurred but medical complaints were otherwise as expected. Medical monitoring data remained within accepted limits other than for elevated methemoglobin levels during the period of use of the Gemini diet.



Fig. 59

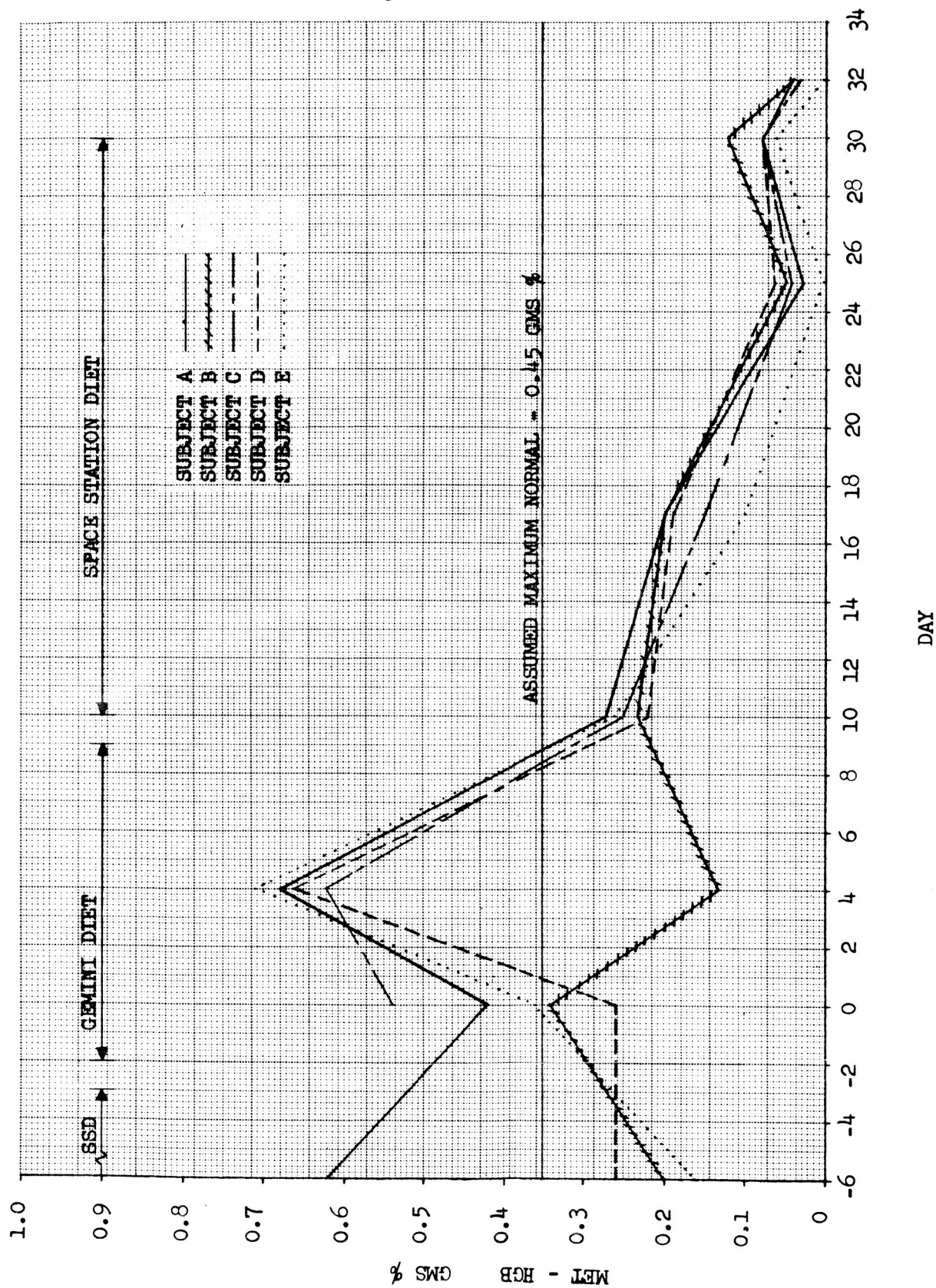




TABLE 55

## COMPARISON OF HGB-MET-HGB LEVELS (3-12-64)

Subj.	% MET Hgb		Gms % Hgb		Gms % MET Hgb	
	SRL	SL	SRL	SL	SRL	SL
D	1.47	1.77	14.7	15.5	.22	.27
A	1.88	1.46	14.3	14.5	.27	.21
C	1.76	2.20	14.1	14.1	.25	.31
E	1.80	1.93	14.5	14.0	.26	.27
B	1.60	1.74	14.3	14.3	.23	.25
Mean	1.70	1.82	14.4	14.5	.25	.26
Control						
X	1.69	1.93	15.7	14.0	.27	.27
Y	1.27	1.63	14.7	14.1	.19	.23
Z	1.97	1.28	13.9	14.7	.27	.18
Mean	1.64	1.61	14.8	14.3	.24	.23

SRL - Scientia Research Laboratory

SL - Suburban Laboratory

## DAILY HEALTH QUESTIONNAIRE

During the past 24 hours have you noted: (Circle YES or NO; if YES, comment briefly)

- |  |     |    |
|--|-----|----|
| 1. Any unusual odor  | YES | NO |
| 2. Irritation of eyes, nose, throat                          | YES | NO |
| 3. Breathing difficulty, wheezing, coughing, sneezing        | YES | NO |
| 4. Change in appetite, desire or preference for food/liquids | YES | NO |
| 5. Change in bowel habit, constipation, diarrhea             | YES | NO |
| 6. Nausea, vomiting, indigestion, bloating, flatus           | YES | NO |
| 7. Change in urinary habit or urine color or odor            | YES | NO |
| 8. Headache, visual disturbance, "dizziness" or "giddiness"  | YES | NO |
| 9. Unusual tiredness, fatigue, difficulty sleeping           | YES | NO |
| 10. In general, I feel excellent, good, fair, poor, terrible | YES | NO |

Any other comments: (regarding yourself, other subjects, test conduct, etc.)

\_\_\_\_\_  
NAME

Physician's Comments:

\_\_\_\_\_  
DATE

\_\_\_\_\_  
TIME

#### 6.5.2.2 Urinary Metabolites

At NASA request biochemical tests were conducted on the subjects as possible indices of stress. Included herein are the results of tests for catecholamins, 17 Hydroxycorticosteroids and calcium. Raw data only are presented and no analyses have been made to correlate with other possible areas of stress.

##### A. Total Urinary Catecholamines

Catecholamines were analyzed by the fluorometric trihydroxylindole methods as described by Jacobs, Sobel and Henry (J. Clin. Endocrin and Metab. 21:305 (1961) but using the isolation procedure (ion exchange resin) of Oesterling and Tse (Amer. J. Med. Tech. 27:112 1961). Catecholamine recovery by these methods was usually within the range of 85 to 92%; the maximum error (precision) was  $\pm 9\%$ .

It is generally held that normal catecholamine values will fall below 300-400 micrograms per day. For practical purposes a value of 100 micrograms per 24 hour period would be a normal value. Analyses carried out during the chamber test (MESA II) yielded values between 50 and 300 micrograms. However, during the final phase of the experiment (See Figure 60 ) concentrations reached extremely high levels (600 micrograms per day).

##### B. Urinary Calcium Analyses

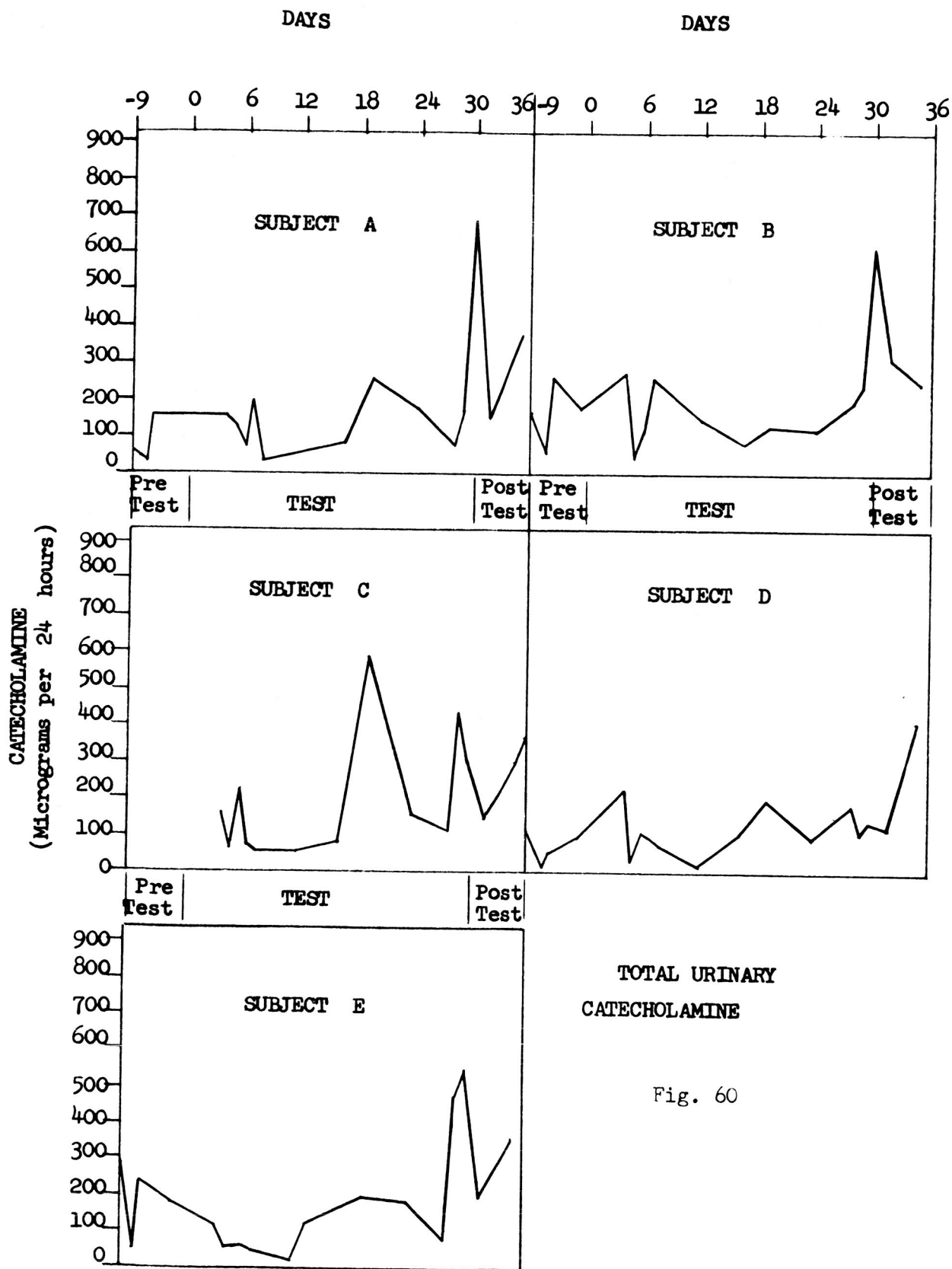
Urine calcium estimates were made on a Coleman Model 21 Flame Photometer in accordance with the directions given in the Coleman Manual #D-248C (Page 37). The normal range for urine calcium is often considered to be 5-15 meq. per 24 hours. Analyses on the MESA subjects gave values between 2 to 21 meq per 24 hours (See Figure 61 ).

##### C. Urinary 17 - Hydroxycorticosteroid

17-Hydroxycorticosteroids were analyzed by the direct method of Norymberski (1). The recovery by this method was generally within 90%. In 8 replicate determinations on one urine sample, the precision (maximum error) was  $\pm 9\%$ .

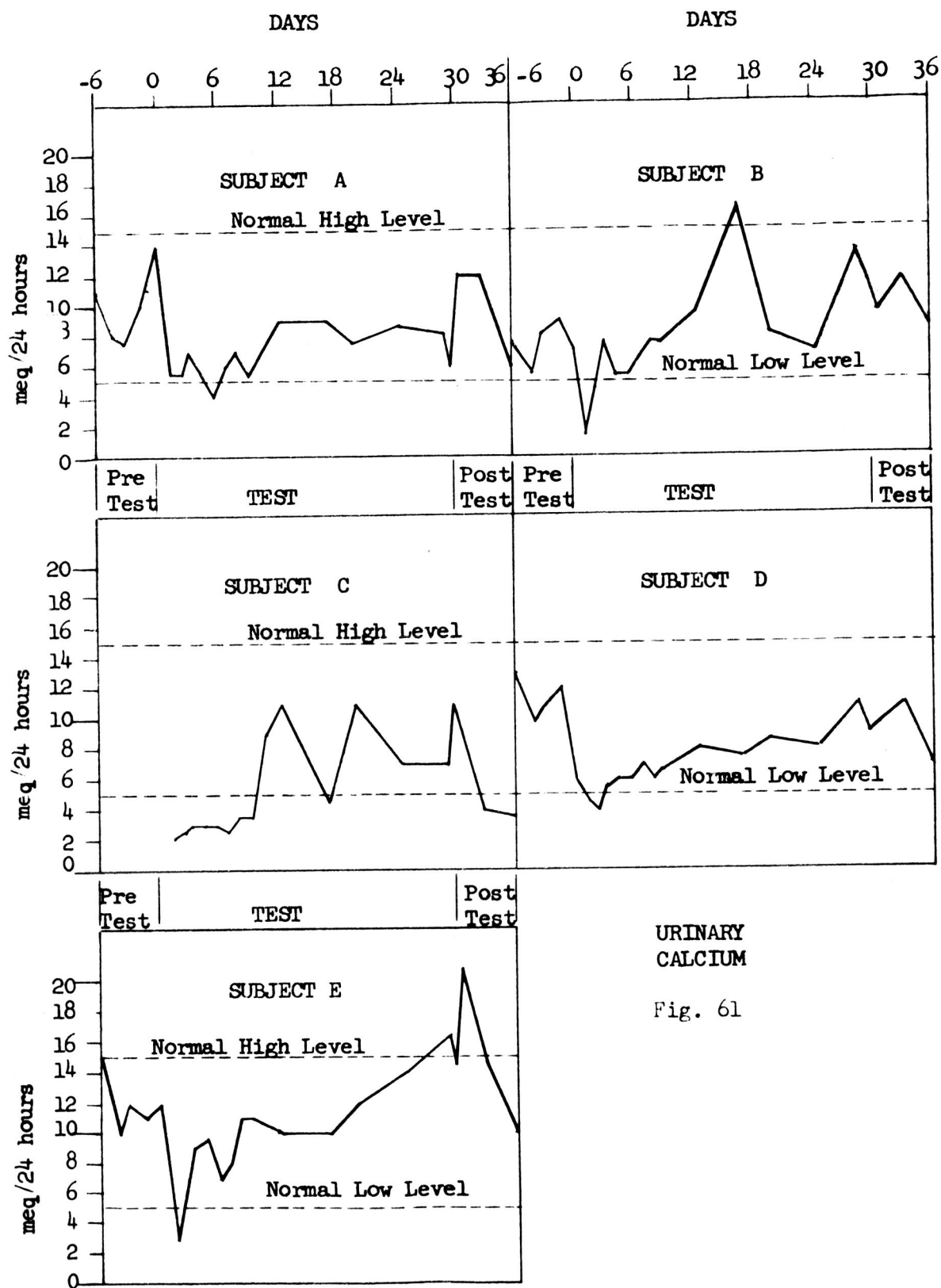
Normal adult males analyzed in this laboratory (cf. picture #2A 171973) had 17-Hydroxycorticosteroids values of 8-25 mg per 24 hours. Analyses on the subjects in the MESA chamber yielded results which had a range of 7 to 45 mg per 24 hours (See Figure 62 ).

Reference 1: Sobel, C.; Golub, O. J.,; Henry, R. J.; Jacobs, S. L., and Basu, G. K.: Study of the Norymberski methods for determination of 17-ketogenic steroids (17-hydroxycorticosteroids) in urine, J. Clin. End. and Metab. 13:208, 1958.



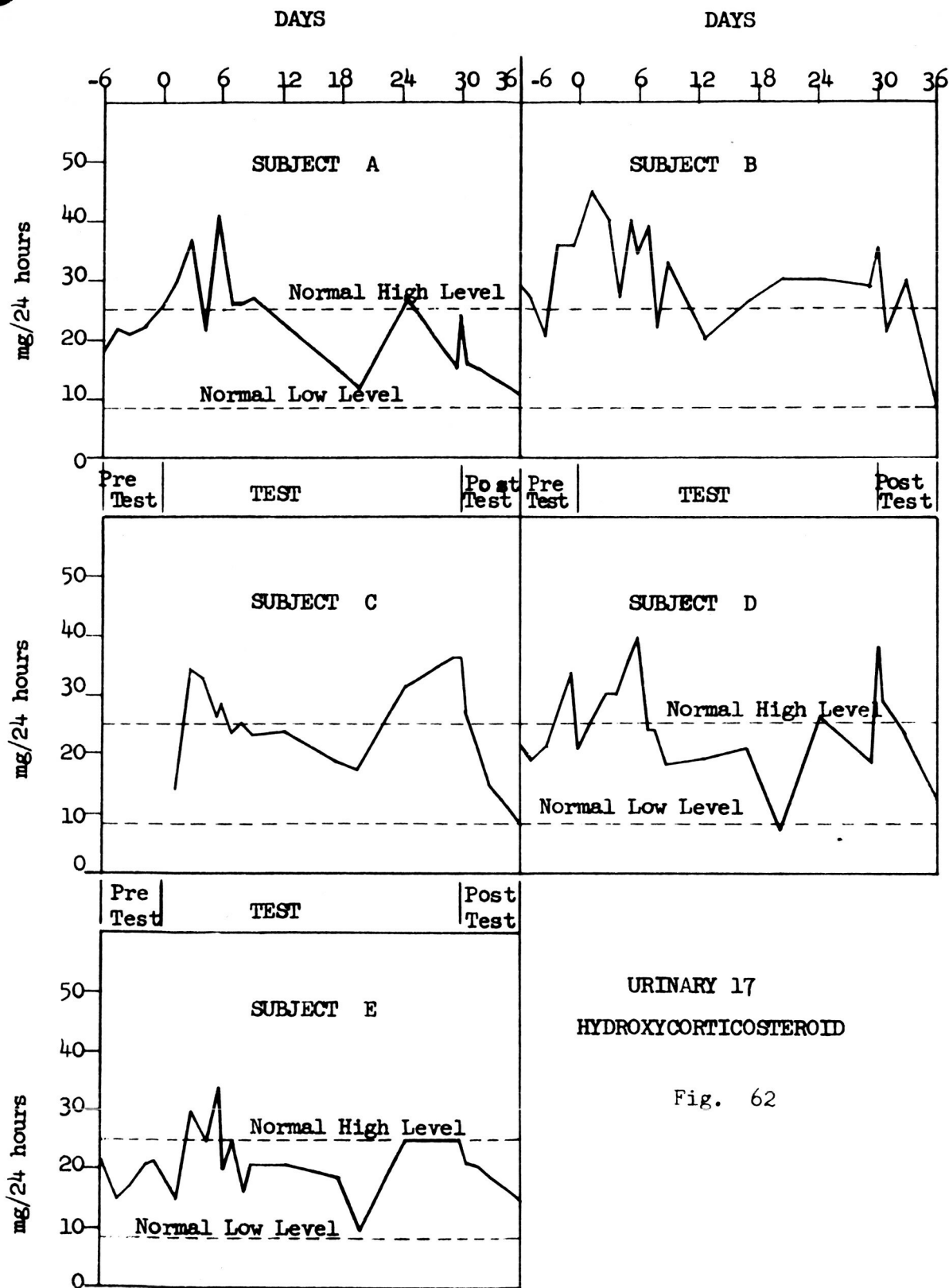
TOTAL URINARY  
CATECHOLAMINE

Fig. 60



URINARY  
CALCIUM

Fig. 61



URINARY 17  
HYDROXYCORTICOSTEROID

Fig. 62

### 6.5.2.3 Bacteriology - MESA II

Bacterial sampling of the subjects included nose, throat, mouth skin and fecal. Samples were obtained from the nose, throat, and mouth by swabbing the same areas each time with cotton tipped wooden applicators. Two of the subjects were given the responsibility of obtaining the samples in the chamber. The importance of proper sampling techniques was emphasized.

#### NASAL SAMPLES

Nasal swabs were obtained from each nostril and smears were made on glass slides for gram staining. Another set of swabs from the nose were obtained at this time and immediately put into tubes of cooked meat medium. The tubes were incubated for 24 hours, then sub-cultured to selective and non-selective media.

Gram stains from the direct smears showed nearly complete sterilization of the nose and nasopharyngeal area a few days after the subjects went into the chamber.

The cooked meat medium cultures were examined for predominant bacterial flora and for any changes of flora that might occur during the test period. Normal predominant flora consisted of *Micrococcus*, *Streptococcus*, and *Staphylococcus aureus*.

During the course of the 30 day test a marked change in the normal flora took place. This change was quite similar for all 5 subjects. The change involved the ratio balance between organisms of the normal flora. *S. aureus* became the predominant organism over all the non-pathogenic organisms to the point of almost obtaining pure cultures of *S. aureus* in the final days of the test. The other organisms had become so few in numbers they were almost non-existent.

#### THROAT SAMPLES

Throat swabs were obtained and put into cooked meat medium immediately. The cultures were removed from the chamber and subcultures made on selective and non-selective media. After the subjects had been in the chamber for a few days the number of bacteria decreased to such an extent the cooked meat cultures had to be incubated 24 hours before subculturing could be done.

Cultures were examined for the presence of predominant organisms, for any changes in the normal flora, and for the appearance of any organisms not previously recovered. The predominant organisms of the throat were *Streptococcus*, *Staphylococcus*, *Micrococcus*, and *Corynebacterium*.

Subject A maintained the normal flora during the first week except for a slight increase of *S. aureus*. On day 20 coliforms were recovered from the throat. By the end of the test *S. aureus* had become the one predominant organism and the other organisms had been reduced to only a few colonies.

Subject B followed about the same pattern as subject A. Coliforms were found, and an increasing population of S.aureus was found until it became the most predominant organism.

Subject C maintained a more normal throat flora throughout the 30 days, However, post-run samples showed a sudden change. S. Aureus had taken over as the predominant organism and Streptococcus had virtually vanished.

Subject D demonstrated a shift from normal flora to an increase of S. aureus by day 12. By the end of the test period S. aureus was practically the sole survivor. The other bacteria had almost been eliminated from the throat.

Subject E. was found to have shifted to almost a pure culture of Streptococcus by the 12th day. By day 20 S. aureus had increased to become equal in numbers with the Streptococcus. At the end of the testin, S.aureus was predominant and Streptococcus nearly non-existent.

#### MOUTH SAMPLES

The mouth flora was examined from stained slides made by swabbing the teeth gums, and tonsil area. The flora, on initial examination 5 days pre-run, consisted of gram positive organisms, Neisseria, a few epithelial cells, leucocytes, and very few organisms of Vincent's angina.

Subject A on day 5 showed an increase of leucocytes and organisms of Vincent's angina. On day 9 Vincent's organisms were found in abundance. The 12th day showed a complete absence of this organism plus an abnormal decrease of all flora. From the 12th day on, the bacterial flora was few in number and there was no evidence of Vincent's organisms except on day 26 when only a few were noted.

Subject B on the 5th day showed a slight increase of Vincent's organisms. By day 9 the organisms of Vincent's angina were in abundance. An extremely heavy flora of Vincent's organisms was noted throughout the remaining test period and on days 3 and 7 post-test.

Subject C showed no change of flora or increase of Vincent's organisms during the 30 days. However, the examination on day 7 showed an abundance of Vincent's organisms.

Subject D on day 5 showed an increase in Vincent's organisms. By day 10 these organisms had increased to a heavy flora and remained heavy until day 22 when the level of Vincent's organisms dropped considerably. On day 26 an increase to moderate flora was noted. An increase to heavy flora occurred on day 29. On the post run examinations the Vincent's organisms had returned to a normal level.

Subject E by the 12th day had a heavy flora of Vincent's organisms. On day 29 no Vincent's organisms were noted, and other bacteria and tissue



cells were rare. On day 7 post run, organisms of Vincent's angina were again found in large numbers.

Figures 63, 64 and 65 show the relationships of the organisms of the nose, of the throat, and of the mouth to each other.

The normal flora of the nose and throat of all subjects declined and coinciding with this was an increase in a potentially pathogenic organism S. aureus until at the end of the test period S. aureus was practically the only organism recovered from the nose and throat.

Each subject, at some time during the test period, had Vincent's angina organisms in concentrations much higher than what is considered normal for the mouth flora.

Further studies should be undertaken to determine the cause of the decline of the normal nasal and throat flora and the subsequent increase of a potentially pathogenic organism. Probably the conditions of temperature, humidity, bacteriological clean air within the chamber or trace quantities of an unknown chemical agent in the air may have caused this condition to occur.

#### SKIN SAMPLES

The subjects did not follow the prescribed procedure for skin sampling; consequently only superficial samples were obtained from the skin. No conclusive or rewarding data could be obtained from this.

#### FECAL SAMPLES

Stool samples were obtained for the first sampling, day 5, with 1 gram wet weight amounts serially diluted to  $1 \times 10^{-13}$ . The remainder of the fecal samples were obtained by using rectal swabs because fresh stool samples could not be obtained from all 5 men on the same day.

Viable counts were obtained by the most probable number method using triplicate tubes in each dilution. Organisms were cultured in the following way:

A. Coliforms

Lauryl Sulfate Broth with Durham tubes - if gas produced culture transferred to E C Medium with Durham tubes - if gas produced organisms identified as Coliforms.

B. Fecal Type Streptococcus

Azide Dextrose Broth - growth transferred to S F Medium - growth and pH change to acid indicates fecal type streptococcus.

C. Other Streptococcus

Blood plates streaked with culture - small streptococcus like colonies gram stained for gram positive cocci. Hemolysis noted from blood plates.

D. Loctobacillus

LBS Broth - growth transferred again to LBS broth - growth gram stained for Loctobacillus rods.

E. Coagulase Positive Staphlococcus

Growth from cooked meat medium streaked on Staphlococcus Medium No. 110 plates - pigmented colonies checked for gram positive cocci and then coagulase tested.

F. Micrococcus

All other gram positive cocci other than coagulase positive Staphlococcus which grew on Staphlococcus medium No. 110.

G. Clostridium

Cooked meat medium cultures gram stained for Clostridium spores.

H. Bacteriodes

Growth found in the highest dilutions of cooked meat medium showing anaerobic growth gram stained for small gram negative rods.

Because the size of the samples obtained could not be standardized, the raw data had to be reduced to a common factor. This was done by calculating the differences in the order of magnitude of the Most Probable Number counts of each organism using the total viable count for each sample as the base line.

Table 56 gives the numbers obtained from calculating the differences in order of magnitude. Bacteriodes is not included in the table because in all cases it was found in the highest

dilutions showing growth and the difference in order of magnitude is zero.

The Clostridium recovered from subjects A and B dropped off considerably on the last 3 samples taken. From subject C, the Clostridium counts stayed fairly constant except on the last sample which shows a drop. The Clostridium from subjects D and E did not change to any extent. The Streptococcus cultured from all 5 subjects fluctuated both in types and numbers recovered. Coagulase positive Staphylococcus was recovered only from subject D on days 5, 19 and 36. The remainder of the organisms cultured remained fairly constant for each subject.

There seemed to be no remarkable changes in the fecal flora of the subjects during or after the test period.

Fig. 63

NASAL FLORA

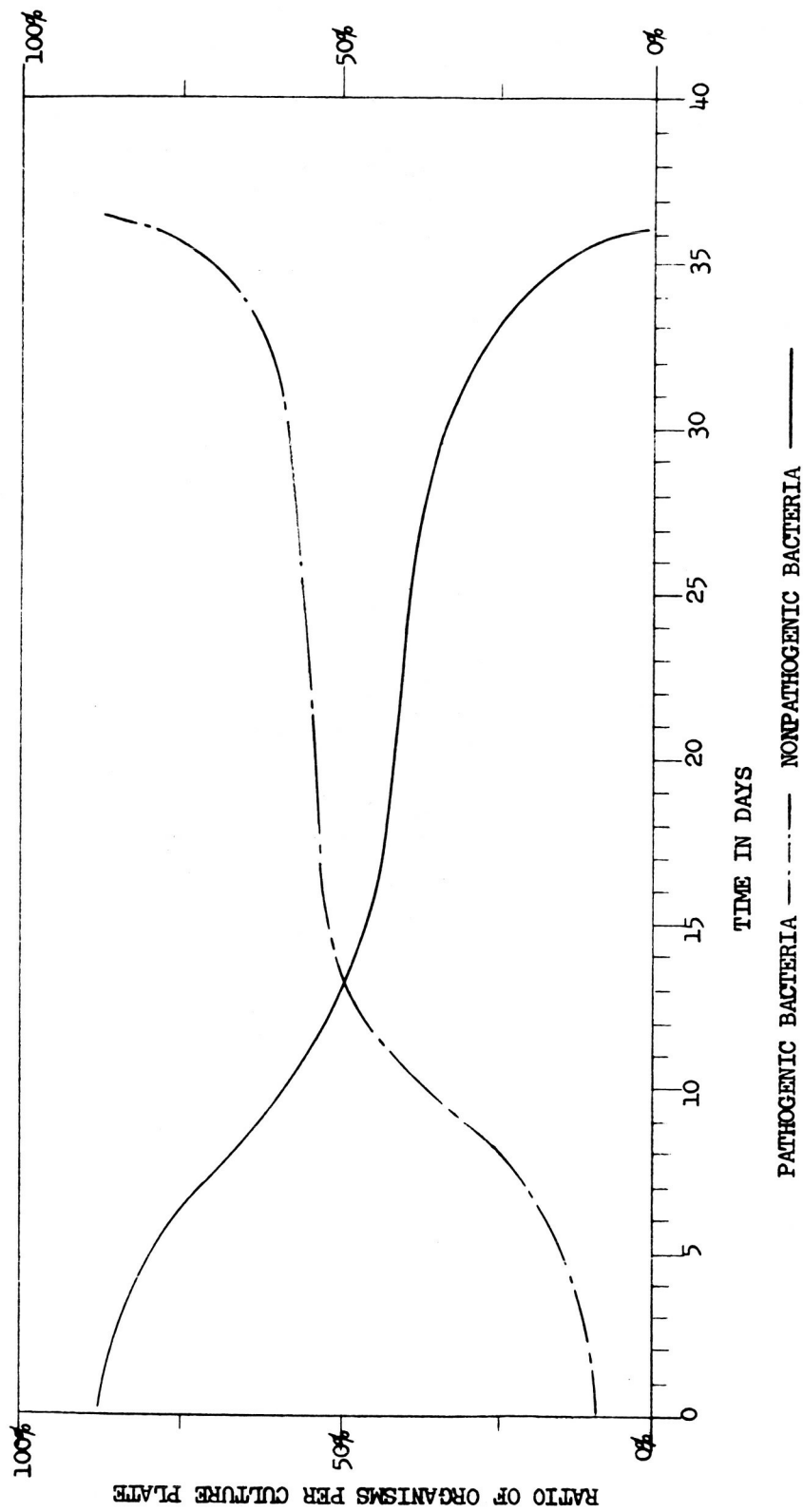


Fig. 64

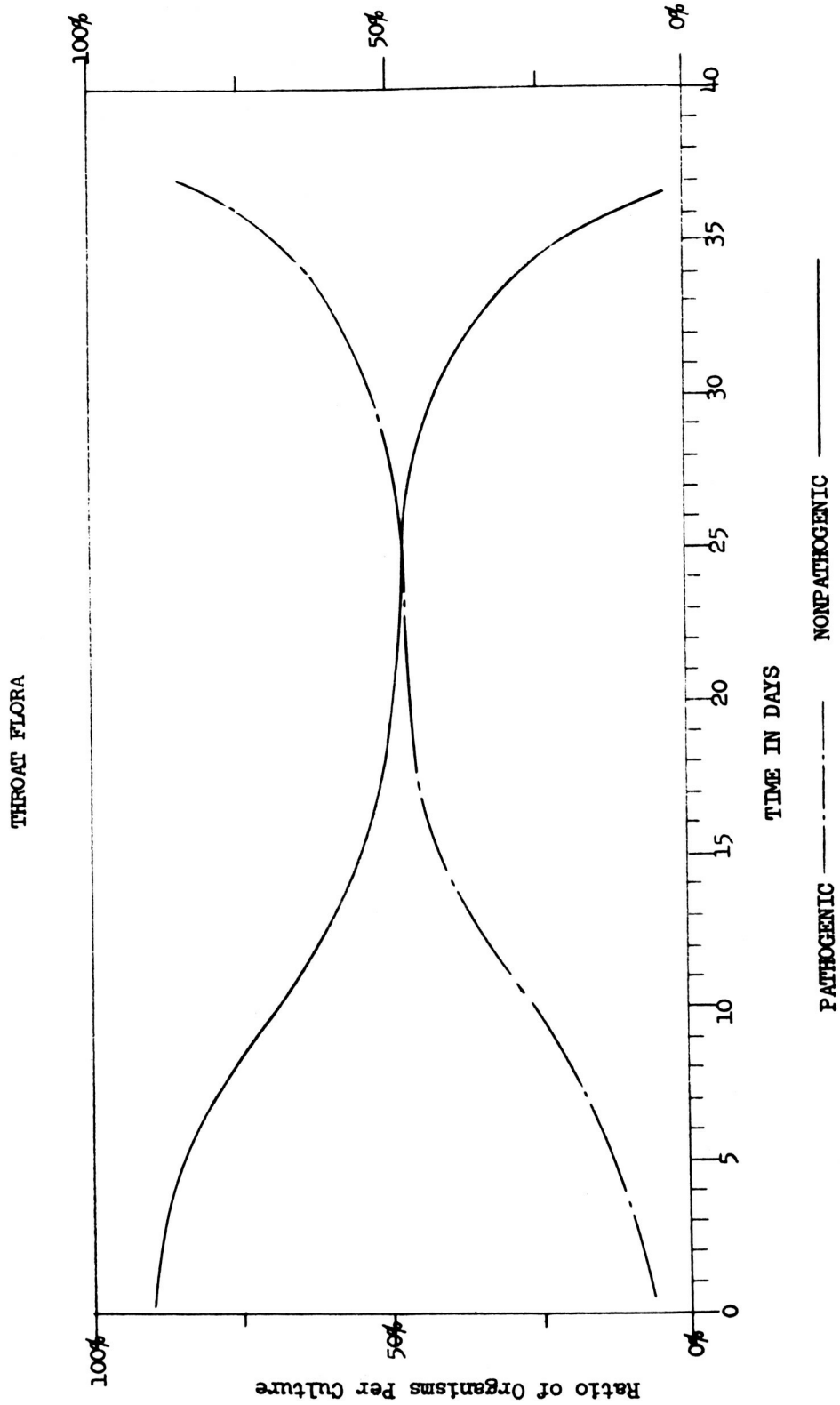


Fig. 65

MOUTH FLORA

SUBJECT A —△—  
SUBJECT B —○—  
SUBJECT C ———  
SUBJECT D —+—  
SUBJECT E —△—

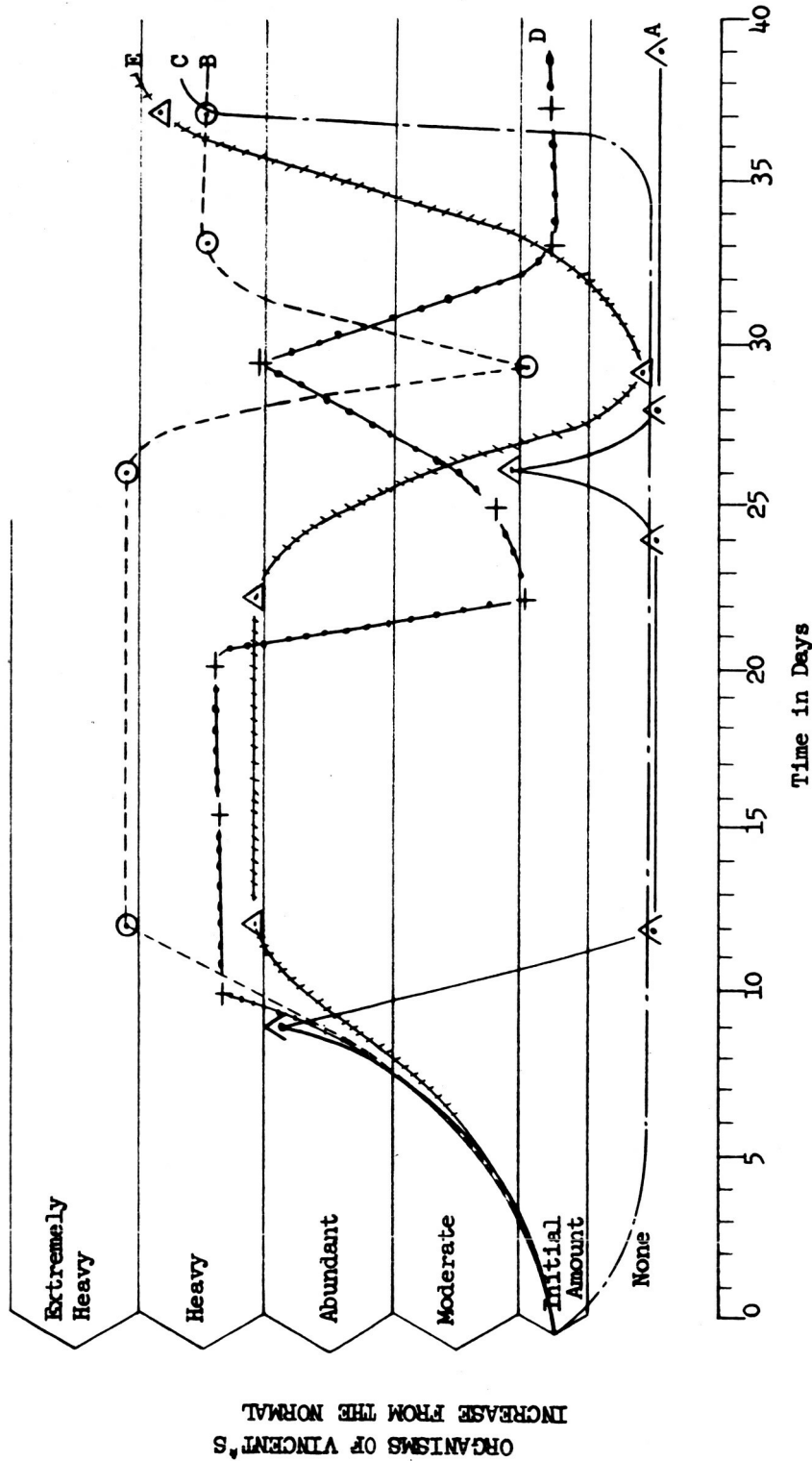


TABLE 56  
COMPARISON OF BACTERIAL COUNTS BY  
DIFFERENCES IN ORDER OF MAGNITUDES - FECAL SAMPLES

Org. \ Day	-5	8	19	27	36	SUBJECT A
Coliform	$1.6 \times 10^3$	$1 \times 10^4$	$1 \times 10^4$	$6.2 \times 10^2$	$9.1 \times 10^2$	
Fecal Type Strep.	$1.6 \times 10^4$	-	-	-	$2.3 \times 10^4$	
Gamma Hem. Strep.	-	$2.2 \times 10^1$	$3.9 \times 10^1$	-	-	
$\alpha$ Hem. Strep.	-	-	-	$6.2 \times 10^2$	$2.3 \times 10^3$	
Lactobacillus	-	$4.0 \times 10^4$	-	-	$9.1 \times 10^2$	
Coag. Pos Staph.	-	-	-	-	-	
Micrococcus	$1.6 \times 10^3$	$5.8 \times 10^3$	$1. \times 10^4$	$4.0 \times 10^2$	$2.3 \times 10^3$	
Clostridium	$5.2 \times 10^1$	$2.2 \times 10^1$	-	$1 \times 10^4$	$4.9 \times 10^5$	
Org. \ Day	-5	8	19	27	36	SUBJECT B
Coliform	$4.6 \times 10^1$	5.3	$1 \times 10^4$	$1.2 \times 10^3$	$6.2 \times 10^2$	
Fecal Type Strep.	$1.9 \times 10^3$	$5.9 \times 10^2$	$4.0 \times 10^3$	$4.0 \times 10^2$	$2.2 \times 10^4$	
Gamma Hem. Strep.	-	-	-	-	-	
$\alpha$ Hem. Strep.	-	-	-	-	$6.6 \times 10^2$	
Lactobacillus	$1.9 \times 10^3$	$2.4 \times 10^4$	$2.2 \times 10^4$	$9.8 \times 10^3$	$2.4 \times 10^2$	
Coag. Pos. Staph.	-	-	-	-	-	
Micrococcus	$3.6 \times 10^1$	$1 \times 10^1$	$2.2 \times 10^2$	$1 \times 10^3$	$1 \times 10^3$	
Clostridium	$2.0 \times 10^3$	$1 \times 10^1$	$4.0 \times 10^4$	$2.2 \times 10^4$	$1 \times 10^5$	

TABLE 56  
COMPARISON OF BACTERIAL COUNTS BY  
DIFFERENCES IN ORDER OF MAGNITUDES - FECAL SAMPLES

Org. \ Day	-5	8	19	27	36	SUBJECT C
Coliform	$1 \times 10^5$	5.3	$4.0 \times 10^1$	$2.2 \times 10^1$	$1.9 \times 10^2$	
Fecal Type Strep.	-	-	-	-	-	
Gamma Hem. Strep.	$4.0 \times 10^3$	$1 \times 10^2$	$1.2 \times 10^2$	-	$5.3 \times 10^2$	
$\alpha$ Hem. Strep.	-	-	-	$1 \times 10^2$	$5.3 \times 10^3$	
Lactobacillus	$4.0 \times 10^5$	$1 \times 10^5$	$4.4 \times 10^3$	$2.2 \times 10^5$	$1 \times 10^5$	
Coag. Pos. Staph.	-	-	-	-	-	
Micrococcus	$1.2 \times 10^2$	$1.1 \times 10^2$	$6.2 \times 10^3$	$1 \times 10^3$	$1 \times 10^2$	
Clostridium	$1 \times 10^2$	$2.5 \times 10^1$	$4.0 \times 10^2$	$6.2 \times 10^2$	$3.1 \times 10^5$	
Org. \ Day	-5	8	19	27	36	SUBJECT D
Coliform	$5.3 \times 10^4$	$1 \times 10^2$	$3.1 \times 10^3$	$4.6 \times 10^2$	$2.2 \times 10^2$	
Fecal Type Strep.	$3.1 \times 10$	-	-	$2.9 \times 10^3$	$6.2 \times 10^3$	
Gamma Hem. Strep.	-	$1 \times 10^2$	$2.5 \times 10^2$	-	-	
$\alpha$ Hem. Strep.	-	-	$1.5 \times 10^4$	$1.1 \times 10^2$	$2.2 \times 10^2$	
Lactobacillus	$3.1 \times 10^3$	$1 \times 10^4$	$1 \times 10^5$	$1.9 \times 10^4$	$4.4 \times 10^3$	
Coag. Pos. Staph.	$2.5 \times 10^5$	-	$5.3 \times 10^1$	-	$2.2 \times 10^4$	
Micrococcus	$1.5 \times 10^2$	5.3	$1.5 \times 10^2$	$2.9 \times 10^2$	$4.0 \times 10^1$	
Clostridium	$1.1 \times 10^2$	$2.5 \times 10^1$	$1 \times 10^3$	$1 \times 10^2$	$1 \times 10^3$	



TABLE 56  
COMPARISON OF BACTERIAL COUNTS BY  
DIFFERENCES IN ORDER OF MAGNITUDES - FECAL SAMPLES

Org. \ Day	-5	8	19	27	36	S U B J E C T
Coliform	$1.9 \times 10^1$	$1 \times 10^2$	$1 \times 10^1$	$2.4 \times 10^1$	$5.2 \times 10^2$	
Fecal Type Strep.	$2.0 \times 10^4$	$2.5 \times 10^4$	$6.6 \times 10^5$	$2.2 \times 10^4$	$8.0 \times 10^3$	
Gamma Hem. Strep.	-	$2.5 \times 10^3$	$1.3 \times 10^6$	-	$1.3 \times 10^3$	
$\alpha$ Hem. Strep.	-	-	$1 \times 10^4$	-	-	
Lactobacillus	$4.6 \times 10^3$	$2.5 \times 10^1$	$6.2 \times 10^2$	$2.2 \times 10^4$	$1.3 \times 10^2$	
Coag. Pos. Staph.	-	-	-	-	-	
Micrococcus	$1.9 \times 10^2$	$1 \times 10^3$	$2.2 \times 10^1$	$1 \times 10^3$	$5.2 \times 10^2$	
Clostridium	$4.6 \times 10^1$	$5.3 \times 10^1$	$2.2 \times 10^3$	4.0	$1.3 \times 10^4$	

## 6.6

## NUTRITION

### 6.6.1

### Introduction

The NASA Manned Spacecraft Center participation in this program included; the provision of food, the indoctrination of subjects to the food concepts, the elicitation of subject diet history, and the tabulation of results received and their interpretation.

The purpose of utilizing prototype space foods was to provide sustenance support to the Boeing Company as well as to supply NASA with additional information on the following:

1. Acceptability of the prototype dehydrated and compressed food items.
2. Evaluation of prototype zero "g" feeders and dispensers.
3. Nutritional data relevant to diet.
4. Physiological data, eg. fecal retardation, relevant to type of diet.

### 6.6.2

### Materials and Methods

Sufficient food was provided for the 30 day test and 8 days of preorientation to the diets prior to the test. A total of 12 man days of Gemini food (2 days preorientation and first 10 days of test) and 26 man days of Simulator Study food (6 days of preorientation and last 20 days of test) was provided for each of five subjects. Two of the five subjects ate from prototype Gemini food containers during the first 10 days of the test. A daily food evaluation record was maintained by each subject (Table I). The menus of each diet are given as an integral part of the acceptability data (Tables II and III). The prototype Gemini menu is a four day cycle menu of 4 meals/day. Each meal provided approximately 650 kilocalories, an average of 2687 kilocalories per man day. The Simulator Study menu is a three day cycle menu of 4 meals/day, providing an average of 2695 kilocalories per man day.

All food for the MESA study was delivered during

the early Summer of 1963. After the abrupt termination of the first MESA study of July 20, 1963, the food remained at the Boeing Company until on or about November 1, 1963, when they were transferred to cold storage (+40°F) at the Seattle Naval Supply Depot until needed for the second MESA study reported herein.

During the pretest period, Crew Systems Division personnel indoctrinated the subjects in the general nature, packaging, and preparation in both menus were of known composition. Plate waste information was requested by CSD to calculate qualitative caloric, protein, and selected mineral consumption data.

#### 6.6.3

##### Results MESA I

The test was initiated on July 30, 1963. Unfortunately, the experiment had to be terminated four and one-half days after the onset because of the presence of an unidentified gaseous contaminant. As early as day one, the subjects reported nonspecific irritation. Definite evidence of a loss of appetite was indicated by two subjects at the start of day three. Nausea was reported midway through day four.

A screening of the limited number of evaluations given to the foods consumed indicates that, except for an occasional individual personal dislike, all food items rated between 5 and 9 on the hedonic scale. The majority of the items received a rating of 6 or better which approximated those ratings obtained by others in nonrelated investigations. In those instances where comparisons could be made, the given rating of an item did not deteriorate more than one point on the hedonic scale, although consumption was falling off during the last two and one-half days of the aborted test.

In summary, the abrupt termination and reported toxic nature of the experiment preclude the calculation of nutritional information. Furthermore, acceptability data reported above is considered unreliable due to the limited number of

ratings obtained and the unexpected outcome of the experiment.

#### 6.6.4

#### Results MESA II

##### 6.6.4.1

##### Acceptability:

Table II presents the average hedonic rating and percent dislike for each prototype Gemini menu food item. Table III presents the same data for the Simulator Study menu food items. Items with hedonic rating of 5.0 to 6.0 are considered **borderline** in acceptability. Items with a rating above 6.0 are considered acceptable. Items with a rating below 5.0 are considered completely unacceptable and usually are not eaten.

The acceptability of the prototype Gemini food, in decreasing order as judged organoleptically by the subjects, is given in Table IV. The same data for the Space Simulator menu items is given in Table V.

##### 6.6.4.2

##### Evaluation of prototype zero "g" food containers:

The subjects' comments about the zero "g" feeder reveal that approximately 10 to 15 percent of the containers were difficult to open and that opening tabs often broke requiring the use of scissors to open the pouches. The seam of several food containers ruptured while kneading the food during reconstitution and when the narrow mouth piece obstructed the free flow of food and increased pressure had to be applied to the food container.

An occasional difficulty arose with the bite size food dispenser in that the tape utilized to withdraw the individual pieces did not function properly if the wrong end of the dispenser was opened due to faulty orientation during packaging.

##### 6.6.4.3

##### Nutritional data relevant to the diets:

Three of the subjects weighed the same before and after the test. One subject lost 3 pounds and one lost 10 pounds by deliberately trying to reduce.

Since no additional data was collected and/or transmitted to CSD, no estimate of caloric or protein balance can be made.

6.6.4.4

Physiological data relevant to the diets:

If the data provided CSD are complete and information provided by the subjects relative to defecation habits during pretest interview are valid, definite fecal retardation, occurred in three of the five subjects, i.e. 8, 14, and 15 bowel movements (b.m.) during a 30 day duration. Two subjects reported little (23 b.m. in 30 days) or no (29 b.m. in 30 days) retardation during the test.

Table IV

Prototype Gemini Food: Order of acceptability under conditions of Boeing MESA Study.

<u>Class of Food</u>	<u>Average Hedonic Rating</u>
Puddings (Chocolate & Butterscotch)	7.0
Beverages and Sea Foods	7.0
Fruit Juices, Fruits, Fruitcake	6.4
Sandwiches (Peanutbutter & Cheese)	6.0
Soups and Cereal Products	5.4
Puddings (Banana & Apricot)	5.0
Meats	4.9
Sandwiches (Meat)	4.1
Bite size (P) and (N) items	3.5
Vegetables	2.5
Overall Menu	5.28

Table V

Simulator Study Food: Order of acceptability under conditions of Boeing MESA Study.

<u>Class of Food</u>	<u>Average Hedonic Rating</u>
Sea Foods and Soup (one only)	7.4
Beverages and Pudding (Date)	6.8
Fruits, Fruit Juices	6.6
Meats, Vegetables, Cereals	6.4
Overall Menu	6.46

Table VI

Comparison of acceptability of identical food products in the test menus.

	<u>Average Hedonic Rating</u>	
	<u>Gemini Menu</u>	<u>Simulation Study</u>
Grapefruit Juice	6.2 (5.3)*	6.6 (7.0)
Fruit Cocktail	6.0 (4.5)	6.7 (6.0)
Shrimp Cocktail	7.7 (7.5)	8.1 (8.3)
Tuna Salad	6.9 (6.3)	7.1 (7.0)
Salmon Salad	5.9 (5.3)	6.7 (6.4)
Beef Pot Roast	6.1 (5.3)	6.4 (5.8)
Beef with Vegetables	5.4 (4.8)	6.1 (5.7)
Bacon (Ham)with Apple-sauce	5.3 (4.0)	4.9 (4.8)
Green Beans with gravy	2.9 (1.0)	3.4 (2.3)

\* ( )\* = average of ratings given for this item by two subjects eating from prototype zero "g" re-hydratable food container. For comparison, average ratings of identical SS menu item as given by the same subjects also is recorded in the SS menu column.

6.6.5

Discussion:

6.6.5.1

Acceptability Data:

The food ratings accumulated during the second MESA study do provide worthwhile information as to the general acceptability of the menus tested. In addition, valuable information was gained as to the susceptibility of the food products to organoleptic changes as effected by long term storage and the adequacy of the prototype packaging.

In view of the nature of the food packaging and its relationship to the natural aging of the foods and the conditions of storage and handling previously described, the food ratings cannot be compared to those expected of similar fresh foods since product deterioration over nine months could be predicted and was expected and no control information was collected. The acceptability of the subject food

items, as compared to fresh items under control conditions, has been determined in other non-related investigations and although some acceptability is compromised by the processing utilized to meet in-flight requirements, all items, when properly package, received at least a 5.0 hedonic rating. Supporting evidence of this was experienced in the first MESA study where no item in the pre-orientation period and the four day test received a hedonic rating below 5.0.

With the exception of three or so Simulator Study food items, the following prototype Gemini foods were judged organoleptically unacceptable:

(a) Vegetables, carrots and green beans, which are very susceptible to oxidation;

(b) Items with low ratings at production time, such as the (N) and (P) bite-size items and in which the coating (P items) or the carrier (N items) is most susceptible to auto-oxidation.

(c) Most meat items deteriorated with the exception of Beef Pot Roast, Beef and Gravy (these items have identical formulations except for the gravy base utilized) and Sausage Patties. All meat items with vegetables received low ratings and deterioration can, in large part, be attributed to the vegetables since the latter received very low ratings per se. Chicken is apparently not as stable as beef under the same conditions.

The overall acceptability of the prototype Gemini diet averaged 5.3 whereas that of the Simulator Study diet, even though it was made up of fewer items, i.e. less variety, and items such as bread and jelly which were used repetitiously, averaged 6.5.

It is noteworthy that several items were identical in both diets and that the average ratings for a given item were, with one exception higher for the product in the Simulator Study diet as compared to the identical item in the Gemini diet. (See Table VI). Three factors which may have contributed to this definite trend in the results are:

(a) the superior quality packaging of the Simulator Study foods as compared to the prototype Gemini foods where two fifths of all items were packaged in Gemini prototype zero "g" food containers. The latter are fabricated from a laminate that does not include the excellent barrier qualities of aluminum foil (See Table VI);

(b) the availability of hot or cold water to reconstitute Simulator Study foods probably was sufficient to increase their acceptability; and

(c) it is possible that the decrease frequency of unacceptable items in the Simulator Study Menu enhanced overall menu acceptance.

#### 6.6.5.2

##### Evaluation of prototype zero "g" food containers:

As a result of Mercury in-flight experiments, both of the subject food containers were discarded by CSD. In addition, to the possible malfunctioning of the bite size dispensers when tapes are utilized, as demonstrated in this study, Mercury in-flight experience also demonstrated that the tapes, after the dispenser is emptied, are difficult to control at zero "g." It is interesting to note that the present Gemini concept includes the use of scissors to open both the rehydratable food and finger food containers.

#### 6.6.5.3

##### Nutritional data relevant to the diets:

The lack of body weight change in three of the four subjects who did not will fully desire to lose weight would imply that, since not all foods provided were ingested, calorie requirements were less than 2500 kilocalories per man day which is in agreement with the data of investigators who have measured mass balance in simulator studies. Subject complaint about the diet not being filling is probably related to the low residue nature of the diets and the decreased need for calories and volume of food to meet actual nutritional requirements.



#### 6.6.5.4

#### Physiological data relevant to the diets:

In general, the low residue nature of the diets is sufficient to promote retardation, but there is considerable individual variation in this response. Since the more acceptable items were primarily carbohydrate, some stimulation may be attributed to these foods. In the data provided CSD no reference to digestive upsets or increased flatulence were made, it is assumed that the digestibility of the diets were adequate as has been reported by other investigators utilizing either one of these diets.

#### 6.6.6

#### Summary

Under the conditions of the MESA study as a whole, the long term acceptability of the prototype Gemini diet was less than that of the Simulator Study diet. Vegetables, all bite size foods (cubes) and many meat items of the prototype Gemini menu were rated unacceptable by organoleptic standards. The following factors contributed to the poor acceptability: (1) auto-oxidation; (2) poorer barrier qualities of zero "g" food container packaging material; (3) requirement for reconstitution of food with room temperature water; and (4) foreign shape, texture, and taste of bite size foods.

Only those food items which received acceptable ratings (6.0 or above) should be considered for inclusion into the flight qualified diets of future long duration missions.

TABLE I  
NASA-Manned Spacecraft Center  
DAILY FOOD EVALUATION RECORD

Subject: \_\_\_\_\_ Weight: \_\_\_\_\_ Date: \_\_\_\_\_

Water Intake:

<u>Time</u>	<u>Volume</u>	<u>Time</u>	<u>Volume</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Food Rating:

Please enter each item eaten. We want to know how you feel about them now. In addition, it will be helpful to know the reasons for your likes and dislikes insofar as possible. Please complete the form. Indicate your preference in the second column using the code numbers given below. Then, if there was a reason why you particularly liked or disliked a food, briefly state it in the third column, along with comments and suggestions.

Codes:

- |                     |                              |                       |
|---------------------|------------------------------|-----------------------|
| 9 - Like extremely  | 6 - Like slightly            | 3 - Dislike moderate  |
| 8 - Like very much  | 5 - Neither like nor dislike | 2 - Dislike very much |
| 7 - Like moderately | 4 - Dislike slightly         | 1 - Dislike extreme   |

	<u>Item</u>	<u>How Well Liked</u>	<u>Reasons for Liking or Disliking, Along with Comments</u>
SS I-A	<u>Orange Juice</u>	_____	_____
	<u>Beef Hash</u>	_____	_____
	<u>Cream of Wheat</u>	_____	_____
	<u>Bread</u>	_____	_____
	<u>Jelly</u>	_____	_____
	<u>Coffee, Cream, Sugar</u>	_____	_____
I-B	<u>Chicken w/gravy</u>	_____	_____
	<u>Sweet Potatoes</u>	_____	_____
	<u>Tomatoes</u>	_____	_____
	<u>Bread</u>	_____	_____
	<u>Jelly</u>	_____	_____
	<u>Milk</u>	_____	_____
	<u>Coffee, Cream, Sugar</u>	_____	_____
	_____	_____	_____
	_____	_____	_____

TABLE II

Prototype Gemini  
Menu Acceptability

Menu	Mean Hedonic Rating	Trials:* <u>Actual</u> Possible	Percent Dislike	Menu	Mean Hedonic Rating	Trials:* <u>Actual</u> Possible	Percent Dislike
<u>Gemini I</u>				<u>Gemini III</u>			
A-Bacon Squares	5.0	9/11	33%	A-Bacon & Egg Pieces	3.8	8/10	75%
Sugar Frosted Flakes	5.6	10/11	30%	All Star Cereal	5.3	10/10	30%
P.B. Sand- wiches	6.2	24/26	8%	T. Bread Cubes	See Meal I-D		
(N)Pine- apple	3.5	2/11	NA**	Apple Cereal Cubes	5.0	7/10	28%
Orange Juice	7.0	23/26	None	Grapefruit Juice	6.2	10/10	10%
B-Tuna Salad	6.9	10/11	None	B-Potato Soup	5.2	8/10	37%
Cheese Sand- wiches	5.8	10/11	20%	Salmon Salad	5.9	10/10	10%
Apricot Pud- ding	5.6	7/11	28%	Beef Sand- wiches	See Meal II-D		
Grape Juice	6.5	24/26	13%	(P)Brownies	4.0	6/10	66%
C-Beef Pot Roast	6.1	11/11	18%	Tea	See Meal I-D		
Carrots in Cream sauce	2.0	2/11	N.A.	C-Beef w/vege- tables	5.4	13/15	30%
Toast	5.3	50/61	20%	P.B. Sand- wiches	See Meal I-A		
Fruitcake I Pineapple	6.3	10/11	10%	(N)Lemon Peel	1.8	6/15	N.A.
Cocoa	7.3	25/26	None	Applesauce	6.5	15/15	7%
D-Soup, Pea	6.0	9/11	30%	Orange Juice	See Meal I-A		
Chicken Bites	4.0	9/11	78%	D-Orange-Grape fruit Juice	6.2	14/15	None
Bread, Cubes, T.	5.5	21/30	14%	Chicken & Vegetables	4.8	12/15	59%
Fruit Cock- tail	6.0	9/11	11%	Toast	See Meal I-C		
T Tea	6.7	36/41	11%	Pudding			
<u>Gemini II</u>				Chocolate	7.2	13/15	None
A-Sausage Pat- ties	5.8	10/10	30%	Pound Cake	2.2	5/15	N.A.
Straw, Cereal Cubes	4.7	7/10	43%	<u>Gemini IV</u>			
Toast	See Meal I-C			A-Ham & Apple- sauce	5.3	14/15	30%
(N)Apricot	4.5	2/10	N.A.	Apricot Cereal Cube	4.7	7/15	28%
Orange-Pine- apple Juice	6.9	10/10	None	Cinn. Toast	6.9	14/15	None
B-Beef & Gravy	5.9	10/10	30%	(N)Strawberry	4.4	5/15	60%
Green Beans/ cream sauce	2.9	4/10	N.A.	Cocoa	See Meal I-C		
				B-Corn Chowder	4.0	13/15	39%
				Beef Bites	3.6	14/15	55%

Menu	Mean Hedonic Rating	Trials:* <u>Actual</u> Possible	Percent Dislike	Menu	Mean Hedonic Rating	Trials* <u>Actual</u> Possible	Percent Dislike
T. Bread				Potato Salad	See Meal II-D		
Cubes	See Meal I-D			(P)Ginger-			
(N)Candied				bread	4.5	10/15	50%
Fruit	3.0	5/10	N.A.	Apple Juice	6.8	13/15	None
Grape Juice	See Meal I-B			C-Spaghetti &			
C-Mushroom Soup	6.1	9/10	11%	meat	4.8	12/15	41%
Chicken Salad	4.5	10/10	60%	Potato Chip			
Toast	See Meal I-C			Blocks	4.4	12/15	41%
(N)Banana	3.2	5/10	N.A.	Chicken			
Tea	See Meal I-D			Sandwiches	3.6	12/15	N.A.
D-Shrimp Cock-				Pudding-			
tail	7.7	9/10	None	Banana	4.4	8/15	50%
Potato Salad	5.9	14/15	29%	Pineapple			
Beef Sand-				Juice	6.8	12/15	None
wiches	4.6	15/20	49%	D-Chicken &			
Pudding-Butter-				Gravy	4.6	9/15	55%
Scotch	7.3	9/10	None	Toast	See Meal I-C		
Tea	See Meal I-D			Fruitcake II			
				Date	6.3	10/15	10%
				Peaches	6.7	12/15	8%
				Grape Juice	See Meal I-B		

\* Actual Number of ratings given over number of time item appeared on menu.

\*\* Not Acceptable.

TABLE III

Simulator Study  
Menu Acceptability

Menu	Mean Hedonic Rating	Trials* <u>Actual</u> Possible	Percent dislike	Menu	Mean Hedonic Rating	Trials* <u>Actual</u> Possible	Percent Dislike
<u>Simulator Study I</u>				Mashed			
A-Grapefruit				Potatoes	See I-B		
Juice	6.7	25/29	8%	Bread	See I-A		
Beef Hash	7.3	14/15	None	Jelly	See I-A		
Cream of				Grape Juice	6.0	11/15	18%
Wheat	6.4	14/15	7%	Coffee, Cream			
Bread	5.1	111/172	9%	Sugar	See I-A		
Jelly	5.6	105/172	3%	C-Beef w/vege-			
Coffee, Cream				tables	6.1	14/14	None
Sugar	6.7	102/130	None	Green Beans	3.4	15/28	67%
B-Chicken w/				Bread	See I-A		
gravy	6.3	15/15	None	Jelly	See I-A		
Mashed Potatoes	6.4	39/44	8%	Date Pudding	6.7	13/14	None
Peas	7.6	21/29	None	Coffee, Cream			
Bread	See I-A			Sugar	See I-A		
Jelly	See I-A			D-Tuna Salad	7.1	14/14	None
Milk	6.6	22/29	9%	Potato Stix	7.3	20/28	None
Coffee, Cream				Bread	See I-A		
Sugar	See I-A			Jelly	See I-A		
C-Pot Roast	6.4	14/14	None	Chocolate			
Whole Kernal				Pudding	5.5	11/14	18%
Corn	5.5	13/14	23%	Milk	See I-B		
Rice	6.6	14/14	None				
Bread	See I-A			<u>Simulator Study III</u>			
Jelly	See I-A			A-Grapefruit			
Pears	6.4	13/14	8%	Juice	See I-A		
Coffee, Cream				Bacon &			
Sugar	See I-A			Applesauce	4.9		
D-Shrimp Cock-				Cornflake			
tail	8.1	13/14	None	Bar	5.7	11/14	18%
Bread	See I-A			Bread	See I-A		
Fruit Cake	6.8	12/14	None	Jelly	See I-A		
Cocoa	7.5	25/28	None	Coffee Cream			
Jelly	See I-A			Sugar	See I-A		
<u>Simulator Study II</u>				B-Salmon Salad	6.7	13/14	None
A-Strawberries	7.8	14/15	None	Potato			
Scrambled Egg	6.9	15/15	None	Sticks	See II-D		
Oatmeal	6.6	15/15	None	Green Bean			
Bread	See I-A			w/cream			
Jelly	See I-A			sauce	See II-C		
Coffee, Cream				Bread	See I-A		
Sugar	See I-A			Jelly	See I-A		
B-Sliced Pork				Fruit Cock-			
w/gravy	6.6	15/15	7%	tail	6.7	13/14	None

Menu	Mean Hedonic Rating	Trial <sup>s</sup> * <u>Actual</u> Possible	Percent Dislike
Coffee, Cream, Sugar	See I-A		
C-Meat Balls w/gravy	7.6	14/14	None
Instant Potatoes	See I-B		
Peas	See I-B		
Bread	See I-A		
Jelly	See I-A		
Coffee, Cream Sugar	See I-A		
D-Chicken Rice Soup	7.5	13/14	None
Chicken w/ vegetables	6.2	11/14	9%
Bread	See I-A		
Jelly	See I-A		
Butterscotch Pudding	5.2	13/14	38%
Cocoa	See I-D		

\*Actual number of ratings given over number of times item appeared on menu.

**BARNICKI, ROGER J.**

DAYS	WBC & DIFF. WBC	WBC & DIFF. WBC					Hgb, RBC RETIC		HEMAT & SED. RATE		WINDROBE INDICES				
		P	L	M	E	B	Hgb.	RBC	Ret.	Hmct.	1/2 Hr.	1 Hr.	MC-HC	MCV	MCH
0-13 7/3 0-5 7/11	7,500	55	39	1	5		15.2	4.99	0.6	46	2 1/2	7	33	92	30
0-1 7/15	9,100	58	40		2		12.9	4.46	0.9	41	2	10	31.5	92	29
0-4 7/20	6,600	47	51		2		13.8	3.86	0.6	43	2	10	32	111	36
ABORT 2:00 P.M.															
DAYS	URINALYSIS						PROTEIN TOTAL A/G g/100 ml.	BUN mg%	Ca mg%	P mg%	K mEq/L	Na mEq/L	PAPER ELECTROPHORESIS		
	Spg.	pH	A	S	Micro										
0-13 7/3 0-5 7/11	1.022	Ac	0	0		Rare WBC & RBC, Few Bact. mucus	7.5	4.1/3.4	26.	10.5	3.2	4.4	140		Hgb. A
0-1 7/15	1.017	Ac	0	0		Occ. WBC. Occ. Ep. Mucus			18						
0-4 7/20	1.023	Al	1+	0		Amorph. mat. Bact. Triple Phos									
FOLLOW-UP PAIRED SERA	Creatinine mg%	Bilirubin Total mg%	Thymol Turbidity units	Transaminase											
				SGOT units	SGPT units										
0-13 Days 7/3	1.0	0.9	0.7	10	4										
0-20 Days 8/5	1.0	1.0	0.4	13	14										

FARRELL, RICHARD J.

DAYS	WBC & DIFF.		P	L	M	E	B	Hgb, RBC RETIC		HEMAT & SED. RATE		WINTROBE INDICES				
	WBC	DIFF.						Hgb.	RBC	Ret.	Hmct.	1/2 Hr.	1 Hr.	MC-HC	MCV	MCH
0-13 7/3	6,150	58	36			6		14.7	5.22	0.5	45	1	2	33	86	28
0-1 7/15	6,150	58	37			5		13.35	4.33	0.8	43	1	3	31	99	31
0-4 7/20	6,650	61	34		2	3		14.2	4.68	0.3	44	1/2	2	32	94	30
ABORT 2:00 P.M.																
DAYS	URINALYSIS						PROTEIN TOTAL A/G g/100 ml.	BUN mg%	Ca mg%	P mg%	K mEq/L	Na mEq/L	PAPER ELECTRO-PHORESIS			
	Spgr.	pH	A	S	Micro											
0-13 7/3	1.017	Alk.	0	0	WBC 0-2/hpf. Amorph. Mat.		7.4	3.8/3.6	17	10.6	2.8	4.5	144	Hgb. A		
0-1 7/15	1.022	ac	0	0	Occ. WBC, Rare Ep. Cell											
0-4 7/20	1.016	Alk.	Tr		Occ. WBC, Bact. Amorph. Trip. Phos.											
FOLLOW-UP PAIRED SERA	Creatinine mg%	Bilirubin Total mg%	Thymol Turbidity units	Transaminase												
				SGOT units	SGPT units											
0-13 Days 7/3	1.0	0.6	0.4	10	3											
0-10 Days 7/26	1.1	0.3	0.4	8	3											
+																



## MESA I

LOWRY, ROMNEY H.

DAYS	WBC & DIFF. WBC		Hgb, RBC RETIC					HEMAT & SED. RATE		WINTROBE INDICES			
	P	L	M	E	B	Hgb., RBC	Ret.	Hmct. 1/2 Hr.	1 Hr.	MC-HC	MCV	MCH	
0-13 7/3	58	40		2		15.65	6.07	0.7	50	1 1/2	31	82	26
0-1 7/15	63	36		1		15.65	5.44	0.4	49	1/2	32	90	29
0+4 7/20	61	38		1		15.2	5.10	0.7	49	1/2	31	96	30
ABORT 2:00 P.M.													
DAYS	URINALYSIS					PROTEIN TOTAL A/G g/100 ml.	BUN mg%	Ca mg%	P mg%	K mEq/L	Na mEq/L	PAPER ELECTROPHORESIS	
	Spg.	pH	A	S	Micro								
0-13 7/3	1.026	ac	0	0	Occ. WBC & RBC Few bact. mucus	7.4	4.3/3.1	18	10.6	2.8	4.1	144	Hbg. A
0+1 7/15	1.028	ac	0	0	Occ. WBC & RBC Few bact.								
0+4 7/20	1.026	ac	Tr	0	Occ. WBC, EP. Cell CaOx Cryst, Bact.								
FOLLOW-UP PAIRED SERA	Creatinine mg%	Bilirubin Total mg%	Thymol Turbidity units	Transaminase									
				SGOT units	SGPT units								
0-13 Days 7/3	1.2	0.8	0.2	10	3								
0+9 Days 7/25	1.1	0.1	0.2	7	2								

WESTLAKE, EDWARD F., JR. (MAJ.)

DAYS	WBC & DIFF. WBC		P	L	M	E	B	Hgb, RBC RETIC		HEMAT & SED. RATE		WINTROBE INDICES				
								Hgb.	RBC	Ret.	Hmct.	1/2 Hr	1 Hr	MC-HC	MCV	MCH
0-13	5,500		55	41		4		14.2	4.44	0.5	43	3	13	33	97	32
0-1	6,650		65	33	2			12.9	4.86	1.1	40	2	8	32	82.5	26.5
0+4	6,500		64	36				14.7	4.53	0.5	46	3	8	32	102	32
DAYS	URINALYSIS							PROTEIN		BUN	Ca	P	K	Na	'PAPER ELECTRO- PHORESIS	
	Spgr.	pH	A	S	Micro	TOTAL A/G g/100 ml.		mg%	mg%	mg%	mg%	mEq/L	mEq/L	mEq/L	Hg. A	
0-13	1.024	Ac	0	0	RBC 3-5/hpf. Occ.WBC Mucus Few bacteria	8.1	4.3/3.8	18	9.5	3.5	4.2	139				
0-1	1.019	Al	0	Tr	Rare RBC & WBC											
0+4	1.022	Ac	0	0	WBC 2-7/hpf Rare RBC, Ep.											
FOLLOW-UP PAIRED SERA	Creatinine		Bilirubin		Thymol		Transaminase									
	mg%		Total mg%		Turbidity units		SGOT units	SGPT units								
0-13 Days 7/3	1.3		0.4		1.1		13	5								
0+20 Days 8/5	1.0		0.9		0.5		12	4								

## MESA I

PROCTOR, CHARLES M.

DAYS	WBC & DIFF. WBC			Hgb, RBC RETIC			HEMAT & SED. RATE		WINTROBE INDICES			
	P	L	M	E	B	Hgb.	RBC	Ret.	Hmat. 1/2 Hr.	1 Hr.	MC-EC	MCV
0-13 7/3	61	36	1	2		15.20	4.93	0.8	46	2	33	93
0-1 7/15	62	36		2		14.2	5.09	1.0	44	1 1/2	32	87
0+4 7/20	52	47		1		14.7	4.58	0.9	46	2	32	100
ABORT 2:00 P.M.												

DAYS	URINALYSIS					PROTEIN TOTAL A/G		BUN	Ca	P	K	Na	PAPER ELECTROPHORESIS
	Spg.	pH	A	S	Micro	g/100 ml.	mg%						
0-13 7/3	1.004	Ac	0	0	One RBC	7.2	4.4/2.8	12	10.0	2.6	3.9	142	Hgb. A
0-1 7/15	1.021	Ac	0	+1	Occ. WBC, Rare RBC								
0+4 7/20	1.007	Al	0	0	Occ. Ep Cell Amorph. Mat. Trip Phos.								

FOLLOW-UP PAIRED SERA	Creatinine mg%	Bilirubin Total mg%	Thymol Turbidity units	Transaminase	
				SGOT units	SGPT units
0-13 Days 7/3	1.0	0.3	0.9	14	8
0+10 Days 7/26	1.1	0.3	1.0	5	7

# MPN COUNTS OF VIABLE ORGANISMS FROM FECAL SAMPLING

Org. \ Day	-5	8	19	27	+6	SUBJECT A
Coliforms	$9.3 \times 10^5$	$9.3 \times 10^3$	$9.3 \times 10^4$	$1.5 \times 10^5$	$2.3 \times 10^5$	
Fecal Type Strep.	$9.3 \times 10^4$	-	-	-	$9.3 \times 10^3$	
Gamma Hem. Strep.	-	$4.3 \times 10^6$	$2.4 \times 10^7$	-	-	
$\alpha$ Hem. Strep.	-	-	-	$1.5 \times 10^5$	$9.3 \times 10^4$	
Lactobacillus	-	$2.3 \times 10^3$	-	-	$2.3 \times 10^5$	
Coag. Post Staph	-	-	-	-	-	
Micrococcus	$9.3 \times 10^5$	$1.6 \times 10^4$	$9.3 \times 10^4$	$2.3 \times 10^5$	$9.3 \times 10^4$	
Clostridium	$2.9 \times 10^7$	$4.3 \times 10^6$	-	$9.3 \times 10^3$	$4.3 \times 10^2$	
Bacteriodes	$1.5 \times 10^9$	$9.3 \times 10^7$	$9.3 \times 10^8$	$9.3 \times 10^7$	$2.1 \times 10^8$	
Org. \ Day	-5	8	19	27	+6	SUBJECT B
Coliforms	$9.3 \times 10^7$	$4.3 \times 10^7$	$9.3 \times 10^3$	$7.5 \times 10^4$	$1.5 \times 10^5$	
Fecal Type Strep	$2.3 \times 10^6$	$3.9 \times 10^5$	$2.3 \times 10^4$	$2.3 \times 10^5$	$4.3 \times 10^3$	
Gamma Hem. Strep.	-	-	-	-	-	
$\alpha$ Hem. Strep	-	-	-	-	$1.4 \times 10^5$	
Lactobacillus	$2.3 \times 10^6$	$9.5 \times 10^3$	$4.3 \times 10^3$	$9.5 \times 10^3$	$3.9 \times 10^5$	
Coag Post Staph	-	-	-	-	-	
Micrococcus	$1.2 \times 10^8$	$2.3 \times 10^7$	$4.3 \times 10^5$	$9.3 \times 10^4$	$9.3 \times 10^4$	
Clostridium	$2.1 \times 10^6$	$2.3 \times 10^7$	$2.3 \times 10^3$	$4.3 \times 10^3$	$9.3 \times 10^2$	
Bacteriodes	$4.3 \times 10^9$	$2.3 \times 10^8$	$9.3 \times 10^7$	$9.3 \times 10^7$	$9.3 \times 10^7$	

# MPN COUNTS OF VIABLE ORGANISMS FROM FECAL SAMPLING

Org. \ Day	-5	8	19	27	+6	SUBJECT C
Coliform	$9.3 \times 10^4$	$4.3 \times 10^7$	$2.3 \times 10^6$	$4.3 \times 10^7$	$1.2 \times 10^6$	
Fecal Type Strep.	-	-	-	-	-	
Gamma Hem. Strep.	$2.3 \times 10^6$	$2.3 \times 10^6$	$7.5 \times 10^5$	-	$4.3 \times 10^5$	
Hem. Strep.	-	-	-	$9.3 \times 10^6$	$4.3 \times 10^4$	
Lactobacillus	$2.3 \times 10^4$	$2.3 \times 10^3$	$2.1 \times 10^4$	$4.3 \times 10^3$	$2.3 \times 10^3$	
Coag. Post Staph.	-	-	-	-	-	
Micrococcus	$7.5 \times 10^7$	$2.1 \times 10^6$	$1.5 \times 10^4$	$9.3 \times 10^5$	$2.3 \times 10^6$	
Clostridium	$9.3 \times 10^7$	$9.3 \times 10^6$	$2.3 \times 10^5$	$1.5 \times 10^6$	$7.5 \times 10^2$	
Bacteriodes	$9.3 \times 10^9$	$2.3 \times 10^8$	$9.3 \times 10^7$	$9.3 \times 10^8$	$2.3 \times 10^8$	
Org. \ Day	-5	8	19	27	+6	SUBJECT D
Coliform	$4.3 \times 10^4$	$2.3 \times 10^5$	$7.5 \times 10^4$	$9.3 \times 10^4$	$4.3 \times 10^5$	
Fecal Type Strep.	$7.5 \times 10^5$	-	-	$1.5 \times 10^4$	$1.5 \times 10^4$	
Gamma Hem. Strep.	-	$2.3 \times 10^5$	$9.3 \times 10^5$	-	-	
Hem. Strep	-	-	$1.5 \times 10^4$	$3.9 \times 10^5$	$4.3 \times 10^5$	
Lactobacillus	$7.5 \times 10^5$	$2.3 \times 10^3$	$2.3 \times 10^3$	$2.3 \times 10^3$	$2.1 \times 10^4$	
Coag. Post Staph	$9.3 \times 10^3$	-	$4.3 \times 10^6$	-	$4.3 \times 10^3$	
Micrococcus	$1.5 \times 10^7$	$4.3 \times 10^6$	$1.5 \times 10^6$	$1.5 \times 10^5$	$2.3 \times 10^6$	
Clostridium	$2.1 \times 10^7$	$9.3 \times 10^5$	$2.3 \times 10^5$	$4.3 \times 10^5$	$9.3 \times 10^4$	
Bacteriodes	$2.3 \times 10^9$	$2.3 \times 10^7$	$2.3 \times 10^8$	$4.3 \times 10^7$	$9.3 \times 10^7$	

# MPN COUNTS OF VIABLE ORGANISMS FROM FECAL SAMPLES

Org. \ Day	-5	8	19	27	+6	SUBJECT E
Coliforms	$2.3 \times 10^8$	$2.3 \times 10^6$	$9.3 \times 10^7$	$3.9 \times 10^7$	$2.3 \times 10^6$	
Fecal Type Strep.	$2.1 \times 10$	$9.3 \times 10^3$	$1.4 \times 10^3$	$4.3 \times 10^4$	$1.5 \times 10^5$	
Gamma Hem. Strep.	-	$9.3 \times 10^4$	$7.3 \times 10^2$	-	$9.3 \times 10^5$	
Hem. Strep.	-	-	$9.3 \times 10^4$	-	-	
Lactobacillus	$9.3 \times 10^5$	$9.3 \times 10^6$	$1.5 \times 10^6$	$4.3 \times 10^4$	$9.3 \times 10^6$	
Coag Post Staph	-	-	-	-	-	
Micrococcus	$2.3 \times 10^7$	$2.3 \times 10^5$	$4.3 \times 10^7$	$9.3 \times 10^5$	$2.3 \times 10^6$	
Clostridium	$9.3 \times 10^7$	$4.3 \times 10^6$	$4.3 \times 10^5$	$2.3 \times 10^8$	$9.3 \times 10^4$	
Bacteriodes	$4.3 \times 10^9$	$2.3 \times 10^8$	$9.3 \times 10^8$	$9.3 \times 10^8$	$1.2 \times 10^9$	

The Most Probable Number counts obtained for the 5 men in the chamber on 5 different sampling dates. The lowest dilution checked in any of the samples was  $1 \times 10^{-3}$ . The dashes in the above table indicate that the particular organism was not found in anyone of the triplicate tubes cultured.

PROJECT WESA II  
CLINICAL EXAMINATION SCHEDULE  
2/24 - 4/7/64

SCHEDULE	DAYS																				
	-7	-6	-5	-4	1	2	3	4	5	6	9	11	17	21	26	29	31	32	33	36	37
Physical Exam				X	X (Brief)												X				PM
Chest X-Ray		X															X				PM
ENG 12 lead, Masters double 2-step		X							BID DURING 30 DAY RUN (Six leads)								X				
Urinalysis		X			X*				X	X	X	X	X	X	X	X	X	X		X	
Urinary Steroids	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X
Collect and hold 24 hour urine	X																	X			
Hematology																					
Routine Blood Work																					
CBC & DIFF., Egb		X			X				X	X	X	X	X	X	X	X	X		X		X
Wact, Sed rate, Retic Count		X			X				X		X	X	X	X	X	X	X		X		
Total Protein, A/G ratio, BUN, Ca, P, K, Na		X											X	X			X		X		X
Egb Electrophoresis		X																			
50 cc paired Sera		X															X				
Specimen Collection																					
Blood																					
Total Blood Drawn		27			6				6		4	8	17	4	6		27		17		15
Oralate		4,2,2			4,2				4,2		4	4,2,2	5,2	4	4,2		5,2		5,2		5
Clotted		10,9										10					10,10		10		10
Urine Specimen Bottle		X			X				X		X	X	X	X	X		X	X		X	
Gallon Jug																		X	X		
Special Container	X			X																	

\*Void and save urinalysis specimen before starting run at 1555 hours. Collect 10% samples of all subsequent voidings for 24 hour steroid and catecholamine determinations. Routine urinalyses will be made on remaining 90% as required.

# PROJECT MESA II - CLINICAL LABORATORY REPORT

BRUNSON, WARREN A. - 2-5000-6188

SWENSON, WARREN A. - 2-5000-6188										30-DAY TEST FROM 2-2-54 TO 4-1-54										REMARKS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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## PROJECT MESA II - CLINICAL LABORATORY REPORT

30-DAY TEST FROM 3-2-64 TO 4-1-64																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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-6	7950	65	35				13.80	5.17	0.7	44	2	4	31%	85	27	Ac	0	0	0	WBC 1-5/hpf. Mucus, Bacteria	1.8	14.2	.2556	A	7.6	4.6/3.0	17	11.4	3.3	4.5	140																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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+4	0	7100	50	44	6		13.35	4.66	0.6	43	1	3	31%	92	29	Ac	0	0	0	Occ WBC Ca Cryst. Bacteria	4.9	13.5	.6615																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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+8	6200	44	48	8			12.90	4.73	0.5	41	1	3	31%	87	27	Ac	0	0	0	Occ WBC Epithel Cryst. Bacteria																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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+10	6400	46	49	2	2	1	13.35	4.93	0.2	43	1	3	31%	87	27	Ac	0	0	0	Occ WBC Mucus Bacteria Ca Cryst.	1.47	14.7	.2161																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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+17	5800	46	49	2	1	2	13.35	4.64	0.3	42	1%	4	32%	91	29	Ac	0	0	0	Occ WBC Rare Epithel Ca Cryst. Mucus	1.38	13.8	1.904																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											</

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PROJECT MESA II - CLINICAL LABORATORY REPORT

ROBINSON, DONALD W. - U. S. NAVY (MC) (LCDR)															30-DAY TEST PERIOD 2-2-64 TO 4-1-64											
DAY	WBC & D.I.F.				HGB REC RETIC.		HEMATOCRIT SED. RATE		WHITBLOOD INDICES		URINALYSIS:				METHUEN-GLOSTIN		FAPER ZINC PHOS		PROTEIN TOTAL A/G		BUN	CA	P	K	NA	REMARKS
	WBC	P	L	M	E	B	HGB	REC	RET	%	1	2	3	4	5	6	7	8	9	10						
	7900	63	36	1	15.20	5.48	0.5	47	2	5	32%	86	28	1.8	Ac	0	0	WBC 1-2/hpf. Nucleus	% HGB GHSX 4.0 15.5 .680	g/100 ml. 7.4 4.7/2.7	mg.% 12	11.4	3.0	4.9	145	
	7500	50	48	1	14.20	5.14	0.8	44	3	11	32%	86	28	1.018	Ac	0	0	Neg.	2.8 15.1 .4228							
	6100	48	51	1	14.20			43	2%	8	33%		25	1.0	Ac	0	0	Ca Ox Cryst. Nucleus Bacteria	4.7 14.5 .6815							
	7700	59	38	3	14.20	5.36	0.5	44	1	5	32%	82	26	1.026	Ac	0	0	Occ WBC Epith. Ca Ox Cryst.								
	6300	50	49	1	14.70	5.36	0.5	45	3	7	33%	84	27	1.018	N	0	0	WBC 0-2/hpf. Nucleus Ca Ox Cryst.	1.88 14.3 .2688							
	5400	51	44	3	14.70	4.98	0.4	45	1	3	33%	90	30	1.03	Ac	0	0	Occ WBC Nucleus	1.35 14.8 .1998	7.9 5.0/2.9	22	11.2	3.7	4.5	141 Methu - 5-19	
	5400	51	46	1	14.70	4.77	0.3	45	1	3	33%	94	31	1.023	Ac	0	0	WBC 0-3/hpf. Some Nucleus								
	7000	45	51	2	14.70	5.24	0.5	45	1%	4	33%	86	28	1.025	Ac	0	0	Occ WBC, Nucleus Karyaline Cast	0.23 13.7 .0315							
	5600	66	30	4	14.20	4.59	0.4	43	2	6	33%	94	31	1.023	N Tr	0	0	WBC 0-2/hpf. Nucleus	0.58 14.3 .0829	7.9 4.3/3.6	21	11.2	2.8	4.2	149	
	5850	53	41	6	14.40			42			34%			1.030	Al	0	0	Occ. Epith.								Serology - Neg.
	8200	35	44	1	15.20	5.07	0.9	46	2	4	33%	91	30						0.25 16.0 .0400	8.2 5.0/3.2	19	10.8	4.0	4.4	141	
	5550	65	32	3	14.20	4.88	0.5	44	2	5	32%	90	29	1.026	Ac	0	0	Occ WBC, Nucleus	7.9 4.2/3.0	19	11.0	3.5	5.4	159		

## • PROVIDENCE HOSPITAL REPORTS

## PROJECT MESA II - CLINICAL LABORATORY REPORT

30-DAY TEST FROM 2-2-64 TO 4-1-64										METHODS																	
URINALYSIS										HEDG																	
DAY	WBC	P	L	M	E	B	HGB	HCT	PCV	MCV	MCH	MC	SPR	A	S	Ac	Micro	%	HGB GMS%	PAPER BLDC FROM	PROTEIN TOTAL A/G	BUN	CA	P	K	MA	REMARKS
Hematocrit										Hematocrit																	
SED. RATE										SED. RATE																	
HCT										HCT																	
HGB										HGB																	
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PROJECT MESA II - CLINICAL LABORATORY REPORT

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WBC & DIFF.										HEMATOCRIT SED. RATE									
HGB HGB EPTIC.										HGB HGB HCV WBC									
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